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Living with floods: key lessons from Australia and abroad

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Jamie Pittock

LIVING WITH FLOODS:
KEY LESSONS FROM AUSTRALIA AND ABROAD

THE AUSTRALIAN NATIONAL UNIVERSITY

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The role of NCCARF is to lead the research community in a national interdisciplinary effort to generate the information needed by decision makers in government, business and in vulnerable sectors and communities to manage the risk of climate change impacts.

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Disclaimer

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Outside cover photo: Road flooding in outer Brisbane area © Liese Coulter

Inside cover photo: Hampden Bridge, Wagga Wagga, location of the city gauge, showing CBD flood levees on the left and the northern floodplain on the right © Eric Wenger.

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CONTENTS

ABSTRACT

Following the serious flood events in Queensland and Victoria in 2010–11, and the reviews that were undertaken subsequently, this project was developed to analyse those reviews to determine whether they offered any lessons for climate change adaptation. Focusing on four major and recent reviews, but drawing on others as well, the project's objectives were to:

- explain the relationships between floods and climate variability, and climate change adaptation
- synthesise the findings from the flood inquiries in Victoria and Queensland by ordering key lessons into frameworks that aid climate change adaptation by end-users
- check the lessons from these Australian inquiries against lessons for more effective flood-risk management that have been identified overseas to explore positive synergies and differences
- refine the draft research finding with advice from end-users through interviews and a committee, and
- communicate the lessons for climate change adaptation and limits to adaptation with key end-users involved in flood risk management.

In addition to analysing the Australian flood reviews, the project also compared review processes and findings with similar processes overseas, including those in the Netherlands, China and the United States, to determine points of similarity that reinforced Australian findings and to explore differences. In addition to analysing the reviews themselves, the project team also conducted a series of semi-structured, in-depth interviews with relevant sectors, including insurance, emergency services, floodplain managers, ecosystem researchers, local government and urban utilities.

The reviews varied greatly in their scope, but one of the most notable findings was that Australian reviews virtually ignored the issue of climate change and its impact on flooding; some reports didn't refer to it at all. The vast majority of recommendations in all reviews pointed to a need for better governance, coordination, integration, policies, strategies, management, management tools, standards, legislation, accountabilities, oversight, communication, resourcing, risk-assessment, planning, education and training. These are all socio-institutional issues, which are vital for the effective implementation of any adaptation measures. In contrast to the Australian reviews, climate change was a driving force behind the international reviewers, and all three international reviews overwhelmingly pointed to a need for ecosystem approaches to flood control. Each of the reports from the Netherlands, the United States and China had important lessons for Australia's flood policies, particularly in relation to structural versus non-structural measures, the role of disaster relief funds, flood insurance and the use of mitigation measures such as voluntary land purchase and relocation.

EXECUTIVE SUMMARY

2010–11 saw some of the biggest flood events in Australia's history, with approximately 80% of Queensland declared a disaster zone and extensive flooding in other eastern states, notably Victoria. The large scale of events, the number of lives lost and the scale of the damage incurred prompted numerous inquiries and review processes by different governments and organisations. As climate change is expected to increase the severity and likelihood of flooding events in the future, a project was developed to analyse these reviews to determine whether they offered any lessons for climate change adaptation.
This report focused on four of the recent reviews, though others were also referenced:

- Brisbane City Council's Flood Response Review Board report (Brisbane Review)
- the Queensland Floods Commission of Inquiry (Queensland Inquiry)
- the Victorian Review of the 2010–11 Flood Warnings and Response (Victorian Review)
- the Parliament of Victoria's Environment and Natural Resources Committee Inquiry into Flood Mitigation Infrastructure in Victoria (ENRC Inquiry).

The project compared review processes and findings with similar processes overseas, including in the Netherlands, China and the United States, to determine points of similarity that reinforced Australian findings and to explore differences. It also conducted a series of semi-structured, in-depth interviews with relevant sectors, including insurance, emergency services, floodplain managers, ecosystem researchers, local government and urban utilities. These interviews were used to validate the research and to obtain a deeper understanding of issues relevant to climate change adaptation to flooding. An end-users committee was used to guide research and to identify project communication needs.

The project used the Prevention–Preparation–Response–Recovery (PPRR) framework commonly used in emergency management to assess measures. This enables findings to be presented in a way that is readily understood by end-users. As it also represents a sequential timeframe, it enables assessment of which phase of intervention is most effective. Consideration was also given to questions of cost-effectiveness, multiple benefits and the relative merits of structural and non-structural approaches in different circumstances. Some of the key findings are outlined below.

Review processes and treatment of climate change

One of the most notable findings was that Australian reviews virtually ignored the issue of climate change and its impact on flooding; some reports didn't refer to it at all. The ENRC Inquiry was the only one of the four to make a definitive statement on climate change effects on flooding when setting the context for the review, but even it did not assess the suitability of the measures it proposed to address future threats. This contrasts markedly with overseas reviews, where concerns that climate change will significantly worsen future flooding are generally a driving force behind the process – as reflected in their terms of reference.

Australian review findings

Australian reviews varied greatly in their scope. The Queensland Inquiry and the Brisbane Review covered all PPRR phases. The Victorian Review was very much focused on response, though preparation and immediate recovery were also covered. The ENRC Inquiry focused on selected aspects of prevention, largely constrained by its terms of reference to consideration of infrastructure.

Perhaps because the reviews concentrate on analysing an event just passed, they appear to under-estimate future risks and adaptation needs. These risks are not only due to climate change but also future population pressures and movements. This is particularly apparent in the Queensland Inquiry, which seems to assume stationarity of weather patterns in its

discussions on flood mapping, and building codes for development on land that has been identified as flood prone.

The reports overwhelmingly point to the need for improvements in non-structural measures, such as development planning, production and availability of quality flood management information, emergency response management and community participation. All reviews were cautious about recommending structural measures such as use of levees and other engineering methods. Where levees were viewed as appropriate, it was mainly in terms of protecting existing urban development or individual assets. Significant failings were found in terms of levee regulation. Dams generally were found to have mitigated the effects of flooding (including in the case of Wivenhoe Dam). The likelihood that they might have encouraged development of flood prone land below them, increasing the consequences of flooding, was not covered. There were some issues surrounding dam safety that might be a cause for concern if they are to cope with increased amounts of water in the future due to climate change.

Only the ENRC Inquiry looked at the management of natural assets on a landscape scale as a method to address flood impacts, and this was limited to the management of riparian vegetation and debris. The Queensland Inquiry touched on vegetation management, but yielded no recommendation. The ENRC Inquiry found that in most cases the common practice of vegetation clearance had a negligible effect on flood depth, while vegetation growing in and around rivers had a significant benefit and reduced the effects of flooding on a catchment scale. Vegetated waterways effectively reduced peak discharge, depth and floodwater velocity, although they slightly increased flood duration. This challenges popular perceptions and practices of removing vegetation from watercourses.

Community resilience is a measure that is currently receiving a lot of attention, and if climate change is expected to deliver large-scale flood events in the future, helping people to become more self-reliant will be a benefit if emergency services are overwhelmed. Recommendations relate to information availability, communication and risk awareness. The Victorian Review reported successful outcomes using the FloodSafe program. However, the same report also noted significant difficulties in modifying human behaviour as opposed to more proactive approaches such as development controls.

The vast majority of recommendations in all reviews pointed to a need for better governance, coordination, integration, policies, strategies, management, management tools, standards, legislation, accountabilities, oversight, communication, resourcing, risk-assessment, planning, education and training. These are all socio-institutional issues that are vital for the effective implementation of any adaptation measure.

Overseas findings

In contrast to Australian reviews, overseas reports overwhelmingly pointed to a need for ecosystem approaches to flood control. The Netherlands and China rely heavily on dyke systems and, while they are strengthening key dykes, they are dismantling or allowing ‘flow through’ of others. In the Netherlands, ‘Room for the River’ programs put in place measures such as levee setback, land purchase and reversing channel-straightening activities to give more room for water to flood in. These programs have a strong focus on integrating the interests of stakeholders to find optimal solutions, resulting in multi-functional landscapes and minimal conflict. In China, logging bans and revegetation of upper catchments are combined with reversing land reclamation practices that have seen large inland lakes shrink by as much as 80%. The aim of these measures is to reduce significant erosion and sedimentation issues, and to increase the water storage capacity of the landscape. Integrated river basin management is a very important element in Chinese measures.

In the United States, ecosystem approaches are also being received favourably, as the limitations and costs associated with structural approaches become more apparent. Indeed,

the Federal Emergency Management Agency actively promotes an ecosystem approach, and discourages the use of levees in floodplain management courses and textbooks. Numerous reviews and reports present a convincing case for the view that levees are an expensive measure that should only be used as a last resort.

The US reports also look in some detail at the role of flood insurance (this being a federally backed scheme), the adequacy of the 1 in 100 year event standard and government disaster relief and mitigation funding. It was the United States that first developed the 1 in 100 year standard, and influenced its use in Australia. It is interesting to note that its origins were purely arbitrary, selected as a tool to implement the national flood insurance plan. The numerous reports and review processes studied pointed to its inadequacy as a standard, with most recommending the standard be increased to 1 in 500 years – particularly for urban areas, where the consequences of flooding are greater and evacuation more difficult. The Netherlands, unlike the United States, takes a highly conservative approach to planning controls, and in some coastal areas the safety standard is as high as 1 in 10 000 (1 in 1250 for riparian areas). With 50% of its land area below sea level, it cannot afford any mistakes, and manages floods with the consequences of failure in mind.

The US reports provide a cautionary tale as far as the provision of disaster relief goes, as over-generous disaster relief can remove the incentive for communities to put in place adequate preventative measures. The United States increasingly is moving towards mitigation, with 15% of disaster relief funding being required to be spent on mitigation. For the United States, this often means voluntary land purchase and relocation. Evidence suggests that this has resulted in billions of dollars of savings in avoided damage costs from subsequent flooding events. In view of enormous taxpayer expenditure following the recent floods and the virtual impossibility of obtaining approval to rebuild to more flood resilient standards, these findings are highly relevant to Australia.

Interviews with Australian experts

Interviews revealed strong support for development controls by the vast majority of participants. However, some significant issues were identified that will need addressing. Competing priorities between managing for flood risk and making affordable housing available was one issue raised. This is significant because it is often people of low socio-economic status or the elderly who are located in flood-prone areas, because such areas are more ‘affordable’. Thus it is a very discriminatory hazard. This has implications for the community resilience approach, as disadvantaged groups are the ones with the least capacity to address risks. Numerous other issues were identified, including the lack of availability of flood-free land in some areas; the limitations of development approval processes and flood studies that are done on a local rather than a catchment scale; lack of accountability and consequences for those who make development decisions; and difficulties involved with rezoning land when there are inadequate resources to provide compensation.

Generally interviewees were not in favour of levees as a solution to flooding, particularly on a landscape scale. Numerous issues were identified by participants with regard to the use of this approach. However, in common with Australian reviews, there was support for the use of levees for existing urban development and for the use of ring levees to protect individual properties.

In terms of response, flood warnings and flash flooding, evacuation, flood planning and community resilience were key concerns, and recommendations in the reviews relating to these were supported.

Another strong finding was the potential for the use of ecosystem approaches to flood management, by reducing damaging floodwater velocity (it is velocity that causes the greatest damage to assets) and flood depth. Crucially, these approaches also delay flooding,

which is of value in increasing warning times. As climate change is likely to bring more intense rainfall, this could be of use in addressing increased flash flooding.

Unsurprisingly, ecosystem approaches tended to be strongly supported by ecosystem researchers and floodplain managers, although other sectors had less familiarity with these approaches and were more cautious. Positive examples of the cost effectiveness of this approach were provided, with measurable cost benefits for water supply and water quality. To enable this approach, a greater focus on a catchment scale approach to planning and implementation is needed, and funding mechanisms such as payment for ecological services schemes would have to be investigated. Incorporation of ecosystem approaches is needed in flood management courses that currently have an engineering focus, and the level of understanding about such measures also needs to be raised among decision-makers and the general public.

There was strong criticism of the government's lack of funding for flood mitigation and betterment, and many found disaster relief over-generous and untargeted. It was not felt that disaster relief in its current form would increase Australia's resilience to disaster. This is a significant issue if the government wants to improve Australia's capacity to adapt, and lessons could be learnt from the United States about merging recovery efforts with mitigation planning.

The insurance industry appears to have limited means of factoring climate change projections into policies due to the need to be cost competitive, though interviews suggest this is more likely to be achieved if local flood studies incorporate climate change scenarios. However, the industry is very vulnerable to losses if it under-estimates risks. The best way to position itself could be to facilitate and provide incentives for policy holders to undertake flood-prevention measures, and there is also the potential for it to offer new products – such as optional extra coverage to enable repairs and rebuilds to improved standards. Such measures could help to reduce the exposure of the insurance industry to future losses.

1 INTRODUCTION AND METHODOLOGY

This project was funded by the National Climate Change Adaptation Research Facility, through its 'Synthesis and Integrative' research program.

Climate change is expected to result in weather events that are less predictable, and disasters such as floods could change in both magnitude and frequency (UNFCC 2006; IPCC 2007; Smit et al. 2000). It is anticipated that the outcomes of recent flood inquiries could hold important lessons for climate change adaptation in Australia. The aim of this research is to investigate measures proposed in recent Australian flood inquiries, and to evaluate which of them show most promise for adaptation to changing flood patterns.

The project objectives are to:

- explain the relationships between floods and climate variability to climate change adaptation
- synthesise the findings from flood inquiries in Victoria and Queensland by ordering key lessons into frameworks that aid climate change adaptation by end-users
- check the lessons from these Australian inquiries against lessons for more effective flood risk management identified overseas to explore positive synergies and differences
- refine the draft research findings with advice from end-users through interviews and a committee, and
- communicate the lessons for climate change adaptation and limits to adaptation with key end-users involved in flood risk management.

1.1 Methodology

Project methodology includes a combination of approaches, including a literature review, key end-user interviews and the use of an end-users committee to guide research and communication products.

While recent Australian flood inquiries are the primary source of information, experience of past inquiries suggests that problem framing may restrict inquiries and their findings (Handmer & Dovers 2007). Additional sources of information will therefore be used to validate the inquiries' key findings and to ensure that important factors are not overlooked. These alternate sources include findings from similar processes overseas, the project's end-users committee and interviews with key end-users. These means will both enhance and validate the research.

The findings and recommendations have been assessed through ordering key lessons into a framework that will aid climate change adaptation by end-users, allowing systematic evaluation of the benefits, risks and costs of the different adaptation measures for local application. The research also looks at the co-benefits and opportunities of certain measures, and identifies the risks of maladaption or overly narrow solutions.

1.2 Literature review

The project conducted a literature review of the relationships between floods and climate variability to climate adaptation. It synthesised findings and recommendations of a number of inquiries into the 2010–11 floods in eastern Australia. These include:

- Brisbane City Council's Flood Response Review Board report (May 2011);
- the Queensland Floods Commission of Inquiry (interim report August 2011; final report March 2012)
- the Victorian Review of the 2010–11 Flood Warnings and Response (interim report June 2011; final report December 2011).

While the project brief only set out to analyse these three review processes, researchers also decided to assess the findings of a fourth inquiry that was released shortly before project submission:

- the Parliament of Victoria's Environment and Natural Resources Committee Inquiry into Flood Mitigation Infrastructure in Victoria (August 2012).

None of the reviews integrates climate change into its findings, or considers how best to address this threat. The Victorian Review (final report) mentions climate change just twice, the most pertinent instance being in the context of property values being adversely affected by flood risk assessment (p. 196). It is not mentioned in the Brisbane Review or in the Queensland Inquiry's interim report. The final Queensland report only considers climate change in isolated instances. These include incorporation of climate change in Brisbane flood studies, council liability for property down-zoning and impacts of sea level rise on stormwater systems, and a quote that includes climate change in a list of review issues (pp. 45, 99, 129–30, 237). The ENRC Inquiry refers to climate change on three occasions (pp. 9, 18, 42), primarily when setting the context of the review. It thus makes the greatest acknowledgement of this issue. However, the main body of the report does not assess individual measures in terms of their suitability to cope with future flooding scenarios. Given the general lack of consideration given to climate change, a process was needed to determine which issues and recommendations covered in the reviews were most relevant to climate change adaptation.

The approach taken here is to examine review findings in terms of the five flood variables identified in Section 2 of this report (i.e. flood magnitude, frequency, location, duration and timing). For example, if a review discusses inundation in areas not previously known to be flood prone (and therefore not covered by a flood warning system), this is obviously relevant to the 'geographic location' variable. Thus it is possible to deduce that broadening the coverage of flood warning systems is a relevant measure for climate change adaptation. Each issue identified as significant is the subject of discussion under sub-headings. These findings are then compared with findings in similar processes overseas (see below).

The lessons and recommendations are analysed using the standard emergency management framework used in Australia, provided through the Commonwealth body Emergency Management Australia, and also through the Council of Australian Governments (COAG)'s National Disaster Resilience Strategy. This framework breaks up phases of emergency management into Prevention/Mitigation, Preparation, Response and Recovery (EMA 2004; COAG 2011) – otherwise known as PPRR. The framework is suitable for a number of reasons. First, it is an established system for managing emergencies, so findings can be presented in a structure widely understood by end-users. It also has the advantage of being able to divide disaster management into temporal phases. Past research indicates that intervention in some phases can be more effective and cost-efficient than others (BTRE 2002). Dividing measures into established emergency management phases could therefore assist to identify the measures that hold most promise for climate change adaptation.

Consideration was also given to standard floodplain management typologies, in particular those developed by Gilbert F White (1945), who divided floodplain management measures into structural and non-structural. Structural measures include engineering solutions such as levees, dams, floodwalls, detention basins and channel straightening. Non-structural measures include management approaches such as building codes, land use planning, legal frameworks, warning systems, emergency management, education and insurance. Research by both White and more recent researchers points to the considerable benefits of taking a more non-structural approach that makes better use of natural flood control (Freitag et al. 2009). This suggests that would be useful to analyse the emphasis of structural versus non-structural measures in the Australian flood reviews, and was therefore also noted.

The project compared the outcomes of Australian inquiries with similar processes overseas to identify similarities and analyse differences. Findings were compared with examples of adaptive management of floods from China, the Netherlands and the United States. Reference material and feedback were supplied by recognised experts from those countries. This component of the research will inform the project with regard to the extent to which the lessons from the Australian inquiries are consistent with those from similar processes in these other countries.

1.3 Interviews

In order to validate findings from the literature review and to gain a more in-depth understanding of issues relevant to climate change adaptation, interviews were conducted with individuals who had experience and expertise in fields relevant to the project. These fields included emergency management, insurance, local government, floodplain management and ecosystem research.

Potential interviewees were selected via a number of processes. The project's end-users committee (comprising individuals from the above areas of expertise) was asked to nominate people it felt would be suitable. The project's primary investigator, supervisors and additional investigators also have expertise and contacts in these areas, and contributed to the list of people to be approached.

Prior to interviews being conducted, the proposed research was submitted to the ANU's Human Ethics Committee. This was approved by the Committee on 28 February 2012. Sixteen in-depth, semi-structured interviews (including a total of 19 interviewees) were conducted using the attached topic guide.

1.4 End-users committee

An end-users committee was formed at the project proposal stage. The committee includes stakeholders in the fields of emergency response, ecosystem research, insurance, floodplain management and local government. The role of the end-users committee was to provide sources of information relevant to the project, nominate potential interviewees and advise on priorities for research and communication products.

2 SETTING THE SCENE

Australia is a country that oscillates between long periods of drought and shorter periods of flood. It is the world's driest inhabited continent, and also has the greatest annual rainfall and runoff variability. Much of this variability is a result of the Southern Oscillation, which varies atmospheric circulation, causing cyclical alternations between El Niño and La Niña conditions (Smith 1998; Pigram 2007). Given the natural variability of the climate from year to year, it is sometimes assumed that Australians are primed for adaptation to a changing climate. Certainly, many approaches to dealing with climate variability have been tried, discarded or refined. However, natural climate variability can also cause Australians to dismiss climate change threats on the basis that natural variability is more significant.

The susceptibility of Australian settlements to flood hazards is largely a legacy of the country's early colonial history, when agricultural settlers selected riverine sites of fertile floodplains on which to build. These early farmers lacked knowledge of Australia's climate, its rainfall and variability. Even when it was discovered that such sites were subject to major flooding, most towns refused to relocate. Over time, these settlements grew, exposing increasing numbers of people and property to flood damage.

After the initial settlement phase, various solutions to flooding were tried. Starting in about the 1930s, people tried raising houses above perceived maximum flood levels or building on mounds. Some houses had to be raised multiple times as knowledge of flood risk grew. Levees were used at this time, but not in any integrated way – partly because large-scale systems are expensive operations that often need government funding. It was not until the late 1950s that state governments became involved in the construction of levees, and assistance for such structural solutions increasingly became available from 1973. These new levee systems tended to be planned and integrated. More recently, non-structural measures, including land planning, emergency management and education, have increased in importance (Smith 1998).

This report examines various measures for managing future flood events in eastern Australia. While the emphasis is on climate change adaptation, the measures analysed are expected to be equally applicable to address the natural variability of Australia's climate, regardless of threat magnifiers such as climate change and the uncertainties they introduce.

2.1 Impacts of climate change on flooding in Eastern Australia

Anthropogenic climate change[1] will come on top of natural variability, and is expected to exacerbate natural extremes of flood and drought. Flood characteristics are likely to change due to global warming, and we can no longer rely on historical data to predict floods:

> Due to changing climate, the frequency and magnitude of floods in the near future is expected to vary across Australia. It has been established that changing climate will have notable impacts on the rainfall runoff process and thus hydrologic time series (e.g. flood data) can no longer be

[1] Any reference to 'climate change' in this report refers to anthropogenic climate change caused by greenhouse gas emissions unless otherwise specified. It does not refer to natural variation due to short or long climate cycles or natural phenomena. For further detail on how both hydroclimatic drivers will be incorporated into Australian regional flood estimation, see Engineers Australia's current revision of the Australian Rainfall and Runoff guidelines at <http://www.arr.org.au/Website_links/ARR_General_Flyer.pdf>, viewed 10 January 2013.

> assumed to be stationary. It has serious implications in regional flood estimation, as these are based on past data, which can no longer be taken to represent the future under a changing climate regime. A failure to take climate change into account can undermine the usefulness of the concept of return period, and can lead to underestimation/overestimation of design flood estimates, which in turn will have important implications on the design and operation of water infrastructure. (Rahman et al. 2010)

A rise in the global mean temperature of between 1.4 and 5.8ºC above 1990 levels is expected by 2100. This will change flood patterns due to changes in precipitation and sea level rise. There is expected to be increased precipitation intensity, as higher sea surface temperatures result in greater evaporation and warm air can hold more water vapour. Changing circulation patterns will affect rainfall distribution (Meehl et al. 2007).

Sea level rise (SLR) is among the best-known effects of climate change, and in recent years projections have regularly been revised upwards as information has improved. The upper projection for SLR in the IPCC's Fourth Assessment Report (2007) was 0.79 m by 2100. Shortly after this, CSIRO developed three scenarios for SLR that incorporated more recent evidence. These ranged from 0.496 m to 1.1 m by 2100, with 0.819 m being comparable with the IPCC AR4's moderate scenario (A1FI scenario). Projections presented at international fora in 2009 ranged from 0.75 m to 1.9 m by 2100. This has implications for planning and adaptation (Australian Government 2009).

Australian sea levels are increasing, but at different rates. The oceans on the central east and southern coasts of Australia are rising at a rate of around 3 mm per year – similar to the global average – whereas the north and north-west Australia have been rising 7–11 mm per year. At this point, the rises are linked primarily to warming of ocean waters, causing them to increase in volume (CSIRO & BoM 2012).

The 2007 IPCC report indicates that while rainfall intensity will increase, rainfall over eastern Australia is likely to decrease overall. Modelling also indicates seasonal changes, with rainfall increasing in summer but decreasing in winter, particularly in the south. The report also anticipates that tropical cyclones will increase in intensity (Christensen et al. 2007), though it is not yet known whether the number of cyclones will change.

Sources refer to a range of flood variables (Bates et al. 2008; Westra 2011). These include:

- geographic location
- frequency (of both large and small events)
- timing (seasonal)
- magnitude (as measured by volume, depth, area inundated, precipitation intensity, rate of rise, velocity)
- flood duration.

Studies rarely address all flood variables, and most focus on flood intensity and frequency. However, a survey of government documents from the eastern states of Australia indicates that all these variables are likely to be relevant to eastern Australia.

2.1.1 Queensland

Queensland's *Climate Change: Adaptation for Queensland Issues Paper* examines more flood variables than most, possibly because it was published subsequent to the recent floods in 2010–11. It looks at possible changes to flooding in the climate change scenario of 2ºC above pre-industrial levels (equivalent to stabilising CO_2 emissions at 450 ppm). The *Issues Paper* indicates that there will be changes to seasonal patterns, as well as increases in intensity. Interestingly, there is little mention of changes in flood

frequency as it applies to Queensland. Changes in flood variables covered in different parts of the paper include:

- changes in distribution of rainfall and frequency and intensity of flood (in Australia)
- the likelihood of seasonal and daily patterns of rainfall intensity increasing flood risk (in Queensland)
- extreme rainfall events expected to intensify (in Queensland)
- an increase in the frequency of two-hour, 24-hour and 72-hour extreme rainfall events for large areas of South-East Queensland
- the likelihood of rainfall associated with tropical cyclones (within 300 kilometres) increasing by approximately 20% on average by 2100
  – the frequency of tropical cyclones expected to stay the same or decrease
  – cyclones occurring further south
- increased extent of coastal flooding
- in some places, increased risk of flooding in what were previously considered low-risk areas
- the likelihood of mid- to high-risk flood areas experiencing more severe flooding (Queensland Government 2011a)

The recently published national *State of the Climate 2012* report anticipates increased spring and summer monsoonal rainfall across the north, with a 66% probability of fewer cyclones but an increased proportion of intense cyclones (CSIRO & BoM 2012).

In terms of SLR, the Queensland government currently uses 0.8 m by 2100 for planning purposes. However, in its issues paper it notes that this is likely to be an under-estimate (Queensland Government 2011b, p. 13).

2.1.2 NSW

The *State of the Climate 2012* report suggests decreased late autumn and winter rainfall in Australia's south due to circulation changes and drying over southern and eastern areas during spring (CSIRO & BoM 2012). Seasonal changes may not alter overall flood risk, but they are likely to have implications for natural resource-based industries such as agriculture.

Studies by the NSW government on changes to flood behaviour focus on changes to flood frequency, height and extent, noting that all these are expected to increase. As in other states, problems are expected to be exacerbated in coastal areas by the interaction between catchment and coastal flooding caused by sea level rise (State of NSW 2010).

2.1.3 Victoria

Studies by the Victorian government indicate that there will be increased rainfall intensity and seasonal changes, including an increase in summer and autumn rainfall and a decrease in winter and spring rain. Flooding is expected to be more frequent and intense (Victorian Government 2010).

Increased rainfall intensity is supported by findings of Melbourne Water, whose study of possible future flooding events found that, on average, rainfall intensity over five urban catchments in Melbourne was likely to increase and that the interval between large-scale events would decrease. Using existing tools and models, Melbourne Water found that a 30% increase in rainfall intensities was likely by 2030, at which point there would be a period of pseudo-stationarity until 2070:

> While results varied from catchment to catchment typical results from this analysis indicated the 2070 1 in 5 year design ARI[2] event was equivalent to the present 1 in 10 year ARI event and the 2070 1 in 100 year ARI event was equivalent to the 1 in 300 year ARI event. (Pedruco and Watkinson 2010)

2.2 Other factors likely to influence flooding

Changing precipitation patterns and sea level rise are not the only factors influencing flooding. Others include storm surge, land subsidence, soil movements (due to increased erosion), population increase, urbanisation (associated with impermeable surfaces that increases water run-off), landscape modifications (e.g. levees), vegetation cover and soil moisture level. Many of these can also be related to climate change to some degree.

Vegetation cover in Australia is likely to become sparser due to climate change, because of more prolonged droughts. Sparser vegetation impairs the ability of the landscape to diffuse raindrop intensity, to slow run-off and to absorb moisture. According to Nott (2006, p. 52), such landscapes are more likely to have high run-off and more destructive flash flooding.

Drier catchments are also likely to decrease soil moisture levels. This may be a positive aspect for decreasing flood intensity, as dry soil can soak up more rainfall, resulting in reduced run-off. However, having catchments that are drier overall may be of limited advantage if rainfall is of long duration and if there are a number of rainfall events in close succession.

Sea level rise will not only causes inundation of low-lying properties but will also affect the frequency of storm surge events. For example, in South-East Queensland, a major 1 in 100 year storm surge event is expected to occur every 14 years with a sea level rise of 0.8 m (Queensland Government 2011b, p. 17).

Land subsidence is rarely considered, but could be a significant issue in some areas due to groundwater extraction. For example, subsidence could cause coastal land in some parts of Gippsland to sink as much as 1–2 m, exacerbating flood risk (McInnes et al. 2005). With increasingly dry conditions and rising populations, pressures on groundwater resources leading to subsidence can only be expected to increase.

2.3 Adaptation to changing flood behaviour: natural variability versus climate change

Increased exposure to flood will impact on life, property, infrastructure, environment, health (including injury and exposure to chemical and pathogenic pollutants), society and livelihoods (Bates et al. 2008). According to a report by the CSIRO, there will be a 100% increase in the number of Australians exposed to risk of flooding if average global temperatures rise between 1 and 2 degrees (Preston & Jones 2006). There will be increased likelihood of death and injury, and property damage is expected to be substantial. A sea level rise of 1.1 m could potentially expose more than $226 billion worth of Australian coastal assets to flooding and erosion (Australian Government 2011).

Hydrologists have been aware of non-stationarity for more than 20 years, and in the last five to 10 years have started to understand the physical mechanisms behind that

[2] The Average Recurrence Interval (ARI) is a statistical estimate of the average period in years between the occurrence of a flood of a given size. For example, a 100-year ARI event will occur on average once every 100 years. This is referred to as a '1 in 100 year flood event' in this report. It is equivalent to the commonly used term 1% AEP (Annual Exceedance Probability), whereby an event has a 1% probability of occurring in any given year.

historical non-stationarity. Non-stationarity of flooding can be related to two things: (1) as per Milly et al. (2008), if the future is not the same as the past (e.g. due to anthropogenic climate change) and (2) if the underlying physical mechanisms that drive rainfall (and therefore flooding) are variable from year to year or decade to decade such that the risk of flooding is elevated or suppressed (i.e. non-stationary) depending on what climate phase you are in.

Flood risks may be compounded by demographic factors. Australia's population of 21 million in 2007 is expected to increase to 35 million by 2049. The largest growth is expected in capital cities and coastal areas. Growth in coastal areas is largely driven by retirement of baby boomers and the 'sea change' phenomenon, which is expected to continue for at least another twenty years. Populations in these areas are particularly vulnerable, comprising highest percentage of people of the lowest income, highest median age and highest elderly dependency (Australian Government 2009).

Adaptation to climate change requires the assessment of increased exposure to these risks, and putting measures in place to minimise them.

According to the 2007 synthesis report of the IPCC, adaptation can be defined as:

> Initiatives and measures to reduce the vulnerability of natural and human systems against actual or expected climate change effects. Various types of adaptation exist, e.g. anticipatory and reactive, private and public, and autonomous and planned. Examples are raising river or coastal dikes, the substitution of more temperature-shock resistant plants for sensitive ones, etc. (IPCC 2007)

It could be argued that improving society's ability to cope with flooding does not require an understanding of whether flooding is a result of climate change or natural variability. Any measures that address flooding will apply equally, regardless of causal factors. This raises the question of how normal flood management differs from climate change adaptation to flooding.

2.3.1 Natural variation

Natural climate variability is influenced by many natural cycles that play out over decades, or even multiple decades. One of the most significant of these in eastern Australia is the El Niño-Southern Oscillation (ENSO). During the La Niña phase, there is significantly higher rainfall and cooler air temperatures, particularly for northern NSW and Queensland (generally 50–100% higher than during El Niño). An increase in rainfall is also experienced in Victoria, but this is much lower. Impacts are usually felt from September to January. The effects of ENSO are modulated by other climate cycles that play out over multiple decades. Research into the Interdecadal Pacific Oscillation (IPO) and its interaction with ENSO shows that it affects the magnitude of ENSO events and that it can also affect the spatial extent of ENSO and the frequency of La Niña events. During the 'negative' IPO phase, rainfall tends to be higher and more predictable compared with the 'positive' phase. Interestingly, while the negative phase of IPO magnifies already enhanced La Niña rainfall and streamflow throughout eastern Australia, the effects are particularly noticeable for southern NSW and Victoria, which are less affected by ENSO when IPO is not in its negative phase (Verdon et al. 2004). These long-term variations demonstrate why it can be hard to determine the cause of climate change, and how much of the observable change is due to natural variation that plays out over long time scales and how much is due to increased greenhouse gas emissions. Hallegatte (2009) notes that in some areas it will be another 40 years before changes in precipitation patterns become statistically detectable and distinguishable from natural variation, and that it is a mistake to wait so long for modelling to be fully validated. This is discussed further below under 'adaptation approaches'.

Natural variation is generally within the 'known' spectrum of climatic conditions that have been experienced historically. As a caveat to this, Australia has extremely short rainfall and runoff records, with the earliest continuous rainfall gauge data generally only dating back as far as the mid-1920s for eastern Australia (Verdon et al. 2004). The likelihood of an event happening in any one year is calculated based on these historical data. This is incorporated into existing planning (e.g. flood levels for a 1 in 100 year flood may be taken into account when planning developments and creating building codes). Thus adaptive measures for natural scenarios *may* already be in play for events of this scale (depending on the quality of information, planning and compliance). Adaptation in this context means that society has judged it viable for flooding on this scale to happen at an average interval of 100 years. That is, the long-term cost of recovery (in economic and social terms) is not so great that it affects the viability of living in a locality (Godden & Kung 2011).

Adaptation for natural variation of greater rarity than 1 in 100 year probability is generally not incorporated into development planning in Australia. For example, in Victoria, 80% of the floodplains plans are mapped using the 1 in 100 year event standard (Comrie 2011, p. 62). If an event is classified as having a probability of 1 in 1000 years, its impacts may be extreme. However the risk of the event happening in any given year reduces to a very low level. The event's improbability makes it lose relevance to planners and people living in the area. It is assigned to 'residual risk' and not addressed (Handmer & Dovers 2007). It could be that there is a greater risk to society in the opportunity cost of abandoning the area in the intervening 999 years[3] or of not using the area to its optimum capacity.

2.3.2 Climate change

Under climate change scenarios, a 1 in 100 event (or other lesser events) may become more frequent (Milly et al. 2008). A rise of only 50 mm would increase the frequency of flooding events in Australia dramatically, and a *coastal* flooding event currently categorised as a 1 in 100 year event would occur several times a year (Australian Government 2009). A recent study to establish a benchmark figure for taking climate change into account when assessing *inland* flooding risk for Queensland suggests that a 2ºC increase in temperature by 2050 would shift the probability of a 1 in 200 year flood event to 1 in 100 years. A 4ºC increase in global temperatures by 2100 would mean that an event currently given a probability of 1 in 500 years would occur every 100 years (Department of Environment and Resource Management & Department of Infrastructure and Planning 2010).

If frequency increases, existing adaptation measures may not be sufficient to ensure the long-term viability of the community as the costs of recovery multiply (Smit et al. 2000). Thus, even if an event is within normal climatic variation and is incorporated into existing planning frameworks, adaptation to natural variation may be insufficient under a climate change scenario.

The crucial point to be made about climate change is that it changes our underlying assumptions about risk. If using a standard risk matrix, the likelihood and the consequences of flooding are both likely to increase. A historically rare event may no longer be assigned to 'residual risk' if its probability magnifies.

Instead of not incorporating improbable events into our planning (and therefore not adapting to them), we will need to consider such events as real possibilities to be addressed. A key aspect of the review of Australian flood reviews is therefore to assess their understanding of how climate change affects risk and any measures they put forward to address this.

[3] Noting that 1 in 1000 year event doesn't actually mean the interval between events will be 1000 years – it actually means the probability in any given year of it happening is 0.1%; it could happen two years in a row and then not again for 2000 years.

2.3.3 Adaptation approaches

Hallegatte (2009) suggests that improved modelling is unlikely to yield the degree of certainty that planners require, partly due to difficulties in distinguishing between natural multi-decadal variability and anthropogenic climate change. Models cannot be validated in the short term, by which time a maladaptive decision may have been made. Moreover, projection ranges continue to be large despite improved information, and uncertainty will remain no matter how good the modelling.

Hallegatte (2009) argues that it is current decision-making frameworks that need to be changed to accommodate this uncertainty, rather than delaying action until information provides certainty. He ranks adaptation options according to a number of characteristics, including no-regrets strategies, reversibility, ease of incorporating low-cost safety margins, soft strategies (which by their nature generally are reversible), avoiding long term commitment (uncertainties increase further into the future) and synergies, which consider externalities to other sectors. 'Institutionalisation of a long-term planning horizon' is an example of a soft management measure that forces planners to look several decades ahead. Other high-priority measures relevant to flood management include climate-proofing of new building and infrastructure, restrictive land use planning, insurance and the development of early warning systems and evacuation systems. Structural solutions and options such as relocation and retreat were less favoured, as they are not reversible or flexible (Hallegatte 2009). Throughout this report, no-regrets, low-cost options that have co-benefits have been identified. Adaptive action of this nature is less hampered by uncertainty.

3 OVERVIEW OF REVIEWS

This section provides an outline of the reviews in terms of their terms of reference, review team composition, review content and broad approach taken in each review.

3.1 Queensland Floods Commission of Inquiry

The terms of reference of the Queensland Review are broad: to make a 'full and careful inquiry in an open and independent manner' on the following:

a) the preparation and planning by federal, state and local governments; emergency services and the community for the 2010–11 floods in Queensland
b) the performance of private insurers in meeting their claims responsibilities
c) All aspects of the response to the 2010–11 flood events, particularly measures taken to inform the community and measures to protect life and private and public property, including:
d) immediate management, response and recovery;
e) resourcing, overall coordination and deployment of personnel and equipment;
f) Adequacy of equipment and communications systems; and
g) The adequacy of the community's response.
h) The measures to manage the supply of essential services such as power, water and communications during the 2010/2011 flood events,
i) Adequacy of forecasts and early warning systems particularly as they related to the flooding events in Toowoomba, and the Lockyer and Brisbane Valleys,
j) Implementation of the systems operation plans for dams across the state and in particular the Wivenhoe and Somerset release strategy and an assessment of compliance with, and the suitability of the operational procedures relating to flood mitigation and dam safety,
k) All aspects of land use planning through local and regional planning systems to minimise infrastructure and property impacts from floods,
l) In undertaking its inquiries, the Commission is required to:
m) Take into account the regional and geographic differences across affected communities, and
n) seek public submissions and hold public hearings in affected communities (QFCI 2011).

The *interim report* focuses on preparation and response issues including dam operation, as it was a priority to resolve any issues surrounding these aspects before the next year's wet season. The recommendations of the interim inquiry were accepted in full by the Queensland government and a commitment made to implement them before the following year's rainy season (Department of the Premier and Cabinet 2011).

The *final report* focuses on land planning and the performance of the insurance industry, these being more long-term prevention and recovery issues (QFCI 2012).

The inquiry was led by Supreme Court Judge Catherine Holmes. Deputy Commissioners included Jim O'Sullivan, a former Police Commissioner, and Phil Cummins, an international dam expert. Four barristers formed the remainder of the team. The makeup of the team emphasises the importance of the preparation and response aspects of the interim inquiry. For the final report, the team was supplemented with expertise in town planning, hydrology, governance and engineering. An area of expertise that seems to be lacking is floodplain management in terms of ecological systems and land use practices, which would have been relevant to point g) of the ToR.

Climate change is not specified in the terms of reference. However, there was scope for the Commission to consider climate change had it wished to do so. Section 3 of the Commissions of Inquiry Order (No. 1) 2011 requires the Commission's report to include (among other things) recommendations that are appropriate, feasible and cost effective to improve 'the preparation and planning for future flood threats and risks, in particular the prevention of the loss of life'. The final phrase, 'prevention of loss of life', was certainly covered. However, 'future' flood threats generally seem to have been interpreted by the Commission in terms of events comparable in scale to the recent floods. Climate change rates no mention in the Commission of Inquiry's initial report, and is only touched on in isolated instances in the final report.

While the significance of climate change is largely omitted in the inquiry reports, the implications for climate change adaptation appear to have been recognised by the Queensland Government's Office of Climate Change (Queensland Government 2011b), and by the Queensland Reconstruction Authority, which incorporates climate change modelling in its flood mapping design scenarios (QRA 2012).

The Queensland Floods Commission of Inquiry will be abbreviated to 'the Queensland Inquiry' when it is referred to subsequently in this document.

3.2 Brisbane flood, January 2011: Independent Review of Brisbane City Council's response, 9–22 January 2011

The terms of reference for the Brisbane review are as follows:

3.2.1 Context

The review is to establish the characteristics of the flood and the resultant levels (including a comparison against the Q100 flood level). These characteristics will provide the context against which the review is to be undertaken.

The review will focus on:

- the effectiveness of BCC's disaster management arrangements (including the Local Disaster Management Group and Local Disaster Coordination Centre)
- the impact of the existing planning regulations in flood-affected areas
- command, control, coordination and communications
- effectiveness and timeliness of public warnings and advice
- information management (including GIS, flood modelling and monitoring systems) and ICT arrangements
- effectiveness of flood prevention and stormwater infrastructure
- analysis of the reasons for BCC's riverine infrastructure failures
- integration of council's response with other agencies
- effectiveness of the response, including:
  - field operations
  - evacuation
  - intelligence management and dissemination
  - forward planning
  - management of supporting agencies
  - logistics planning and procurement arrangements
  - contractor support and management
  - management of volunteers (individuals through to large commercial support)
  - waste and debris management and disposal
  - transition to recovery
  - other issues (such as activation and escalation), to be noted in the report.

Internal aspects are to include consideration of:

- clarification of roles and responsibilities

- systems and data (for collecting, modelling, collating and sharing data)
- emergency shelters/one-stop-shops and recovery centres
- communications between the LDCC and operationally deployed elements (multiple RIMTs)
- interaction between LDCC (FOG, DIG and ISG), FPG, RIMTs and Recovery Committees

External aspects are to include consideration of:

- systems and data (for collecting, collating and sharing data with other agencies)
- the division of responsibilities for emergency shelters/one-stop-shops and recovery centres
- council's relationship with LDMG and the wider disaster-management system (including the DDCC and SDCC).

The report is to summarise the key findings regarding Council's response to the flood events that occurred from Sunday 9 – Saturday 22 January 2011, to document observations and to make recommendations on amendments to plans, procedures, roles and responsibilities, and on improvements that will enhance BCC's disaster management arrangements and the response to future events. (Arnison, Gotterson et al. 2011)

The review board was led by Major General Peter Arnison, AC, CVO, a retired army officer and former Governor of Queensland, currently Chancellor of Queensland University of Technology. Other members of the board included Robert Gotterson QC, a Queensland barrister and Emeritus Professor Colin Apelt, a civil engineer. The composition of the board appeared to lack expertise in floodplain management – perhaps accounting for a focus on engineering methods of flood prevention.

The review terms of reference address all phases of emergency management, including prevention, preparation, response and recovery. However, there is a distinct emphasis on response. Climate change is not mentioned, either in the terms of reference or the content of the report.

The Brisbane Flood January 2011: Independent Review of Brisbane City Council's Response 9–22 January 2011 will be abbreviated to 'the Brisbane Review' when it is referred to subsequently in this report.

3.3 Victorian Review of the 2010–11 Flood Warnings and Response

The Victorian review was much more restricted in its terms of reference than either the Queensland Inquiry or the Brisbane Review. The issues it was required to examine included:

- the adequacy of flood predictions, including technology and modelling techniques used
- the adequacy, timeliness and effectiveness of flood warnings and public information
- emergency services command and control arrangements utilised to manage the emergency
- the adequacy of evacuations of people at greatest risk, including health and aged care facilities
- the adequacy of clean-up and recovery arrangements

- the adequacy of service delivery by state and federal government agencies, local governments and volunteer-based organisations, and
- the adequacy of the funding provided by the state and federal governments in the form of emergency grants in their various categories.

The review was led by Mr Neil Comrie AO, APM, former Chief Commissioner of Victoria Police and current Bushfires Royal Commission Implementation Monitor, suggesting a focus on emergency response. No information appears to be publicly available regarding the expertise of other members of the team.

The interim report is incorporated in a revised form into the final report, forming its introduction and methodology sections (Comrie 2011).

The terms of reference are heavily focused on emergency response. Preparation and recovery are also covered. However, prevention and mitigation appear to have been omitted. The terms of reference contains no apparent provision for considering land planning. However, the reviewers have discussed land planning under the 'the adequacy of service delivery' term of reference, resulting in Recommendation 86. Dam operation for flood mitigation is stated by the review report as being outside the terms of reference, though some of the issues relating to this are discussed in the text.

The review does not address climate change, though it is mentioned in passing on pp. 19, 40 and 196. However, the review does focus on the management of 'large scale or protracted emergency events', two of the climate change flood variables discussed above.

The Victorian Government is not planning to make a formal response to the report. However, discussions at the 2012 Flood Management Association Conference revealed all but three of the 93 recommendations had been accepted.

The Victorian Review of the 2010–11 Flood Warnings and Response will be abbreviated to 'the Victorian Review' when it is referred to subsequently in this report.

3.4 Environment and Natural Resources Committee Inquiry into Flood Mitigation Infrastructure in Victoria

A parallel Victorian inquiry into flood mitigation was undertaken. While beyond the initial scope of this project, it was felt important to include it. The Inquiry's terms of reference are somewhat limited, and make no reference to broader floodplain management or land use planning:

(a) identifying best practice and emerging technology for flood mitigation and monitoring infrastructure including river gauges

(b) the management of levees across Victoria, including ownership, responsibility and maintenance on both public and private land

(c) waterways management, including the nature and extent of vegetation-clearing activities within waterways and their general maintenance

(d) identifying those entities and individuals having ownership of waterways and the responsibility for their clearing and their maintenance, and

(e) the extent to which, if any, local knowledge of residents is employed in effecting waterways clearing and maintenance (Parliament of Victoria 2012).

As it was a Parliamentary Inquiry, the investigating committee comprised members of the Victorian Parliament, from the Liberal, Labor and National Parties. The committee was chaired by Mr David Koch MLC, who has a background in farm management – an appropriate background for this inquiry, both in terms of understanding natural resource management and in terms of issues affecting rural communities. Other members do not have such relevant training, but represent regions affected by floods.

The terms of reference do not appear to include the study of 'soft' approaches to flood mitigation, such as development controls or flood warnings, and the criterion under which this is discussed specifies 'flood mitigation and monitoring infrastructure'. However, the wording also includes 'best practice', which appears to have justified the coverage of measures other than structural ones in the report.

The terms of reference do not refer to climate change. Nevertheless, the report does acknowledge climate change effects on flooding and the need for sound flood management to address this (pp. 9, 18, 42).

At the time of writing, the report had only recently been released and the government had not made a formal response to it. A response is required within six months of the report's release.

The Environment and Natural Resources Committee Inquiry into Flood Mitigation Infrastructure in Victoria will be abbreviated to 'the ENRC Inquiry' when it is referred to subsequently in this report.

3.5 Evaluation of review terms of reference and the extent to which they are covered in reports

The reviews vary in scope, with the Queensland and Brisbane reviews seemingly broad, covering all phases of emergency management (prevention/mitigation, preparation, response, recovery), while the Victorian Review is focused on response and recovery and the ENRC Inquiry on mitigation.

The Queensland Inquiry reports are detailed, examining the mechanics of the disaster, with some illustrative examples to highlight issues and reinforcing its recommendations for improvement. Emergency management deficiencies raised in the inquiry reports have a high degree of correlation with findings of the other flood reviews.

Both the Brisbane Review and the Queensland Inquiry include land use planning arrangements in their Terms of Reference. The Queensland Inquiry (final report) covers this matter in great detail, examining 'all aspects' as directed. The Brisbane Review, burdened with somewhat detailed, response-focused terms of reference, gives land use planning less attention. The report is naturally more limited in analysis than the state funded reviews, but is valuable in providing a municipal viewpoint to emergency management. While recommendations are tailored to the specific management arrangements in place in Brisbane, many of the themes are echoed in other reviews.

The Victorian Review terms of reference are more restricted to emergency response and recovery. The terms of reference of both the Victorian Review and the parallel Victorian Inquiry into flood mitigation make no obvious reference to planning and development controls, although the Victorian Review does address this to some extent as a component of 'service delivery'. Despite the limitations of the terms of reference, the Victorian Review is thorough and displays a high degree of strategic insight.

The review teams seem to closely follow the expertise dictated by their terms of reference. However, floodplain management experts or ecologists who may be expected to have insight into landscape systems and their impact on flooding seem to be lacking.

None of the review terms of reference make any mention of climate change. They are firmly focused on assessing performance during the recent flood event, and on preventing similar events, rather than assessing the adequacy of existing arrangements to address future threats. This finding is of direct relevance to this project, which is charged with studying the flood reviews to determine whether they have any lessons for climate change adaptation. If the reviews did not consider future climate scenarios when making their recommendations, it will be necessary to assess whether recommendations are adequate to address future threats, and to identify which among the recommendations are most useful strategies for adaptation.

4 REVIEW OF ADAPTATION MEASURES IDENTIFIED IN AUSTRALIAN FLOOD REVIEWS

4.1 Flood prevention and mitigation

4.1.1 Dam management

> The drought brought home the value of water; the flood showed its capacity for destruction. These events demonstrated that Wivenhoe Dam is at once the most valuable and dangerous piece of public infrastructure in Queensland. The regulation and control of any such item is a matter of importance to the whole community. (QFCI 2011)

The Victorian Review notes that it was outside its terms of reference to investigate future alterations to the operation of water infrastructure for flood-mitigation purposes (p. 19). Nevertheless, the Review studied the role of dams in the 2010–11 Victorian floods due to community interest. It notes that no dams in Victoria have mitigation as their primary purpose. However, all dams studied for the review to some extent mitigated floods, primarily because peak inflows exceeded peak outflows (Victorian Review, pp. 66–8). A similar finding was made in Queensland for the Wivenhoe Dam (Brisbane Review, p. 14; Queensland Inquiry final report, p. 523).

However, timing of releases is also crucial. The interim Queensland Inquiry pointed to releases of water from the dam being delayed too long according to the operating manual (pp. 55–6). This was confirmed in the final report (p. 504). The Brisbane Review suggests that the timing of the Wivenhoe releases almost coincided with natural river peaks downstream, which impacted Brisbane (p. 14). This is confirmed in the final Queensland Inquiry report, which commissioned flood modelling to ascertain the impact that delaying releases would have had on Brisbane. It found that at the confluence of the Bremmer River, peak flows from both the Bremmer River and the dam releases occurred almost simultaneously. This not only impacted Brisbane but caused significant backwatering for 15 km along the lower Bremmer River, contributing to flooding at Ipswich (p. 524). The major peak also coincided with high tide levels, which further exacerbated the flooding (van den Honert & McAndney 2011, p. 1162). The operation of dams during major flood events is always going to be subject to criticism, but any improvements that can be made to dam management, operating manuals and information to assist optimal timing of releases could potentially have a huge impact on their effectiveness in mitigation.

The vast majority of the recommendations made by the Queensland Inquiry relate to dam management rather than dam infrastructure. Recommendations not relating to management include technology improvements to improve informed decision-making about dam releases, and dam safety issues. The catastrophic consequences of dam failure are well documented. In one of the world's worst dam catastrophes, between 80 000 and 200 000 people are believed to have died when Banquiao Dam burst in China in 1975. This dam was designed to withstand a 1 in 1000 year flood event, but unbeknown to dam operators, another dam further upstream had already burst, adding to natural flows and overwhelming the dam (Pearce 2006). While this may be an extreme example, other dam burst cases commonly cause hundreds of deaths.

Dam safety was an issue influencing the management of Wivenhoe Dam during the floods. The Wivenhoe Dam was constructed following the 1974 floods, which caused enormous damage to Brisbane. Its purpose was not only to ensure water supply; it was also built specifically for flood mitigation. The dam stores 1.15 million megalitres for water supply and has an additional vacant capacity of 1.45 million megalitres (equivalent

to 2.5 times the water in Sydney Harbour), designed to capture floodwaters for mitigation purposes (Seqwater n.d.). Despite this enormous storage compartment for floodwater, the Queensland Inquiry notes that on 11 January 2011, 'Strategy W4 was invoked, for the first time in Wivenhoe's history, at 8.00 am' (p. 78). This is of great significance. W4 is a strategy of uncontrolled water release, which is only used when the dam structure is at risk of failure due to the volume of water it holds. The gates of the dam are opened continuously until outflows match inflows. The Wivenhoe dam was not in any danger of structural collapse, but the fact that Strategy W4 needed to be invoked, despite the dam's enormous storage compartment for mitigation, gives some idea of the pressure under which dam infrastructure may be placed in climate change flood events of increasing magnitude.

While Wivenhoe Dam was sound, in the case of North Pine dam serious questions were raised in the interim report about the dam's capacity to withstand floods. These included both the inaccuracy of the dam's hydrological model (which identified the probability of a flood on the scale of the 2010–11 floods as 1 in 10 000 years, suggesting a gross under-estimation of the size of the flood that the dam may have to withstand), and the gate operating mechanism which was 50 cm clear of being submerged. Had the electric winch submerged, the mechanism would have failed (though there was a back-up petrol generator). There were also serious safety issues for the dam operator who operated controls while standing in high-velocity water halfway up his lower leg (pp. 90–1).

If eastern Australia can expect floods of increasing magnitude under climate change, dam infrastructure needs to be capable of withstanding them, and in view of the issues with North Pine Dam, and other dam safety issues raised in the final Queensland Inquiry report (pp. 591–9, 604), a wider assessment of dam capacity seems advisable. A revision of the dam safety audit process, prioritised according to risk, is recommended (p. 602). The upgrade or decommissioning of unsafe dams is mentioned in the context of one specific dam, but is not discussed as a more widely applicable option (p. 604).

This also highlights another issue: that dams are only effective at controlling medium-scale floods. They will always need to pass very large floods, and may be a less reliable mitigation measure if climate change increases flood magnitude. The interim Queensland Inquiry reports a 'popular misconception that Wivenhoe Dam would contain all floods emanating in the upper Brisbane River' (p. 39). This suggests that, as an extension of Smith's (1998) 'levee paradox', dams can give a false sense of security and encourage development in unsafe floodplain areas.

The inquiry report examines issues such as the conflicting dam management roles of *flood mitigation* and *secure water supply*, and mechanisms to balance these functions. In Queensland, it is the government that has responsibility for determining the appropriate balance between these two functions, not the dam operators. It is somewhat a concern that the final inquiry report finds that 'no Queensland agency has wide ranging responsibility for flood mitigation' (p. 604).

Balancing supply and mitigation functions is not a new problem. As Fred Pearce (2006) notes:

> contradictory hydrological requirements of the different uses to which dams are put. In order to catch floods, reservoirs need to be kept empty; whereas for most day-to-day operations, like feeding irrigation systems and city taps or generating hydroelectricity, they need to be kept as full as possible. Sensitive dam managers try to reconcile these aims. But … The tendency everywhere is to store like hell when you can.

Pearce describes recurring worldwide scenarios where reservoirs are kept close to their full level at the start of the rainy season, so that as they fill, emergency releases of water need to be made to prevent catastrophic dam failure. This results in 'releases that are far greater and more sudden than would have happened during natural river flooding' (Pearce 2006, p. 168).

Prior to the 2010–11 Queensland floods, there was an opportunity to temporarily modify dam management operations from the usual 'secure water supply' function to 'flood mitigation'. La Niña is a highly predictable weather pattern and timely seasonal predictions were provided by the Bureau of Meteorology (BoM) to appropriate decision-makers that La Niña would be unusually intense (interim Queensland Inquiry, p. 46). Improved flood mitigation could have been achieved via pre-release of water from dams to provide extra storage capacity for expected floodwaters, and this option was identified by relevant personnel. Despite this, appropriate measures were not put in place to mitigate the disaster. Administrative systems and chains of responsibility were ambiguous, leading to a breakdown in decision-making. As a consequence, pre-determined full supply levels at Wivenhoe, Somerset and North Pine dams remained unchanged, and dams were already full at the start of the rainy season.[4]

While the management processes that led to the failure for operations to switch to 'mitigation' mode may be specific to Queensland, this does highlight the importance of clear policies, processes, responsibilities and accountabilities. The la Niña event that caused the flood was an accurately forecast and cyclical weather event. If current systems are not adequate to address predictable events, they are unlikely to be able to cope with the added uncertainties of climate change.

Both the Queensland Inquiry and the Victorian Review point to the long drought as being a factor in the 'storage' focus. In Queensland, this was reinforced by the decisions of individuals prior to the event. For example, there was a great reluctance by Seqwater (the dam operator) to act on the (non-directive) from the Queensland Department of Environment and Resource Management (QLD DERM) to reduce the full supply level by 5% prior to the floods (interim Queensland Inquiry, pp. 46–50). Moreover, prior to the flood, the Queensland Water Commission and Seqwater had been looking at options to increase storage of water in dams (increasing the level to which reservoirs could be filled) without increasing their size. This would have had the effect of reducing their capacity for mitigation even further (p. 45).

Both storage and mitigation functions will continue to be crucial as climate change is projected to cause *both* more severe droughts and more severe flood events for Australia (Christensen et al. 2007). The friction between these functions can therefore be expected to increase rather than decrease, so it is important to develop more sensitive, responsive systems and predictive capacity to support this. It is also important to recognise that there will always be a risk of judgement failure in the choice to keep dams full or sufficiently low to catch floods. Dams will never be able to 'flood proof' settlement on floodplains, and cannot be substituted for non-structural measures such as development controls.

4.1.2 Development planning

Development planning is a key measure for flood prevention. If construction in flood-prone areas can be prevented, then the costly damage and social trauma associated

[4] Brisbane City Council commissioned a series of flood studies to determine the correct 1 in 100 year flood level (taking into account the mitigation effects of Wivenhoe Dam). The first study was discarded on methodology grounds, one of the criticisms being "the assumption that Wivenhoe and Somerset dams would be at full supply level at the start of a flood" (final Queensland Inquiry p.49).

with floods can be avoided completely. However, prevention of development in flood prone areas has proved difficult to achieve because floodplain land is attractive for settlement, being highly fertile with easy access to water. Minimising flood impacts through controlling development can be achieved through legislation, construction standards and planning.

Legislative framework

The legislative framework governing land use and development is covered most comprehensively in the final Queensland Inquiry report. However the issues it raises do not seem to be specific to that state alone. Many are also raised in the Victorian Review. For legislation relating to building codes, see Section 4.1.3.

The Queensland government administers development planning through the *Sustainable Planning Act 2009* (Qld) (SPA). The Act allows for the development of the Queensland Planning Provisions, which set out a standard structure for planning schemes and drafting instructions. These Provisions include standard zones and overlays and assessment criteria. In terms of flooding, the Provisions include a standard overlay for flood hazard in the 'development constraints' category. However, the use of the overlay in planning schemes is optional, even where flood mapping information is available (pp. 106–8). In Victoria, the application of the Victoria Planning Provisions that relate to flooding (including standard zones and overlays) only apply if flood mapping has been carried out (pp. 192–4). For more details on flood mapping, see the Flood Information section below.

The SPA also enables the development of State Planning Policies, with which local government planning schemes in Queensland are required to comply. Provisions relating to flood risk are made through State Planning Policy 1/03 (SPP 1/03), administered by the Queensland Department of Community Safety (DCS). This policy is the most important state planning instrument for ensuring consideration of flood risk. In practice, there are significant problems with applying SPP 1/03. One problem is that SPP 1/03 cannot be applied to local planning schemes unless they *both* adopt a 'defined flood event' (identify a historical flood, ideally close to a 1 in 100 year event) *and* have a flood map. Councils that don't include these in their planning schemes can essentially opt out of applying SPP 1/03 to their planning schemes (pp. 97, 118).

Queensland's state planning policies expire after 10 years, and SPP 1/03 is currently being reviewed. The Inquiry report lists some of the matters that are being considered in the review, one of which is resilience to flooding in a changing climate. In this context, the review will be looking at whether there needs to be standardisation for undertaking flood studies and determining a defined flood event; when it is appropriate to use a defined flood event greater or less than the 1 in 100 year flood event standard for residential development; and how to improve the integration of land use planning and disaster management (p. 99).

In addition to improved flood mapping, the Queensland Inquiry recommends the development of *model flood planning controls*. The use of the model flood planning controls would be mandatory in the development application process, regardless of whether council planning schemes include maps identifying areas susceptible to flood. The controls would consist of flood overlay maps, a model flood overlay code and a model planning scheme policy.

The *flood overlay map* would identify land known to be affected by flood; areas affected by flood and subject to planning controls; and areas for which there is no flood information. The *model flood overlay code* would contain planning controls and a consolidated set of assessment criteria (e.g. relating to evacuation routes, building design and hazardous materials). Currently, flood-related assessment criteria are used in planning schemes but

can be scattered throughout the scheme. Consolidation into a single code would ensure consistency and alleviate the drafting burden for councils. The *model planning scheme policy* would provide guidance to applicants about the type of flood information required in their applications. If the application was in an area for which there was no flood information, they would need to include information to enable assessment of whether land is susceptible to flooding. The model planning controls could either be included in the updated SPP 1/03 or in the Queensland Planning Provisions. The Inquiry favours the SPP 1/03, but notes that this would require amendment of the SPA to ensure mandatory compliance with the planning controls (pp. 119–23).

The assessment of local planning schemes by state government agencies in Queensland has not favoured the inclusion of flood provisions. Planning schemes are subject to review by a number of state agencies before a decision is made by the responsible minister about whether to approve them. Recommendations by the Department of Community Safety (DCS) to ensure compliance with SPP 1/03 for significant flood prone areas such as Brisbane and Emerald appear to have been routinely disregarded by the Department of Local Government and Planning, resulting in *non-compliant planning schemes* (pp. 101–3). Issues raised by the DCS for various planning schemes included lack of or insufficient flood mapping, and failure to nominate a defined flood event. In the case of Brisbane's planning scheme, the DCS reiterated its concerns about non-compliance on 16 occasions, 12 of these after the 2010–11 floods. The reasons why the DLGP rejected DCS recommendations could not be explored due to lack of documentation, and the inquiry recommended some procedural and accountability measures to address this.

The Brisbane Review appears to downplay the role of SPP 1/03, stating that it is the product of a prior legislative regime. The review discusses the efficacy of the defined flood level, and briefly mentions recent amendments to the planning scheme (made on the advice of the Lord Mayor's Taskforce on Suburban Flooding), some of which aim to support SPP 1/03 objectives (pp. 55–9).

Application of planning legislation and instruments to address flooding are significantly compromised by *exemptions* (p. 91). While this seems to be a major issue for Queensland, no mention of this is made in either the Victorian Review or the Brisbane Review.

The Queensland Inquiry examined many examples of developments that were exempt from applying SPP 1/03 (see also satellite planning schemes). 'Development commitments' such as 'material change of use that is code assessable' and development where there is overriding need in the public interest are exempt (p. 98). Mining and agricultural activities are not assessable development under the SPA (p. 153). Activities involving hazardous materials are governed by the *Environment Protection Act 1994* (Qld), and are assessed according to 'standard criteria' that make no specific reference to flooding (SPP 1/03 only comes into play when hazardous materials are manufactured or stored 'in bulk': pp. 98, 108, 156). Placement of fill on floodplains to raise soil level to build on can be exempt under certain circumstances, as can placement of fill for infrastructure construction by authorised public sector entities (p. 166). Some aspects of the electricity supply network are exempt developments, and in some planning schemes minor levees can be exempt (p. 169).

Some types of community infrastructure (unless identified in the SPP 1/03 list) are exempt developments. Community infrastructure not covered by SPP 1/03 includes child-care, aged-care, schools and electricity works, among others (p. 149). SPP 1/03 requires community infrastructure to function effectively during and after a flood of a specified flood risk level. This is generally set very low, between a 1 in 200 year and 1 in

500 year event flood level. However, community infrastructure not included the SPP 1/03 definition is not required to meet these standards.

As an illustration of problems with exempt community infrastructure development, the Inquiry offers the case of a Goodna child-care facility. Catering for 115 children, it was built on a site that was flooded in 1974, adjacent to an overland flow path and near the 1 in 20 year event flood line. The centre was inundated to a depth of 1.8 m and had to be evacuated for 45 days. A Yeronga aged care facility was similarly affected. Built in a waterway corridor, evacuation routes were submerged and the site was submerged to a depth of 1 m. Some residents were unable to return for two months (pp. 150, 174, 201).

While local governments are primarily responsible for managing development within municipal boundaries, the final Queensland Inquiry report also investigated the role of the state government in development that was either exempt or where the SPA was not applicable. Examples provided include the electrical sub-station at Milton (pp. 242–4) and two residential towers built on low-lying land, set back from the Brisbane River just 6–10 metres, though above the 1 in 100 year flood level (pp. 175, 190–3). The state government played a prominent part in selecting the residential site and pursued the development, even though it had identified the site as being susceptible to flooding. Access roads flooded some six hours before the buildings were affected, hampering evacuation. Basements were flooded, destroying building services, and some ground-floor flats were also flooded. The residential towers development proved uneconomical, as apartments couldn't be sold; after the flood, the council agreed to buy back the land from the developer (pp. 192, 274). Regarding the substation site at Milton, the state government forcibly resumed land from the electrical company and would only allow it to develop on the least suitable location of the site. The electrical company was faced with large damages when the site it was obliged to use flooded (pp. 242–4). These developments were not subject to SPP 1/03 due to exemption (material change of use) and satellite planning legislation respectively (pp. 197, 242).

To improve consideration of flood risk for exempt development, the Inquiry suggests a number of different measures depending on circumstance. These include *amendments to legislation* (pp. 154, 167, 246); *application of appropriate flood mitigation conditions* for developments unavoidably located in flood-prone areas, that don't rely on human intervention and that provide flexible options (pp. 156–8); and *improved administrative processes*, such as communication between approving agencies and assessment staff within agencies, development of templates and assessment criteria that include flood, improved use of criteria (i.e. reporting against all of them) and clear lines of responsibility for personnel involved in proposal assessment (pp. 155, 158, 198).

Some development, such as that relating to the sewerage network, is assessable development subject to the SPA, but it is also subject to other legislation, such as the *Plumbing and Drainage Act 2002* (Qld). The standards set out in the Act's Queensland Plumbing and Wastewater Code do not include any criteria or any mention of flood resilience. In this case, amendment of the code is recommended (p. 225). This is also relevant to the SPP 1/03 clause exempting 'material change of use that is code assessable', as it shows that not all codes include adequate consideration of flood (p. 152).

Most development in Queensland is administered through the *Sustainable Planning Act 2009* (Qld). However, there are some other planning systems that operate under different legislation (Queensland Inquiry final report, pp. 138–43). These *satellite planning schemes* provide for development such as affordable housing (the aim being to expedite approval of development applications); legislation governing the development of a specified riverside area of Brisbane; state development areas (which can include developments such as hospitals, infrastructure and essential services); and significant

projects (including high value mining projects). Satellite legislation impacts on vulnerable people, including people with lower incomes who require affordable housing, as well as the sick, children and essential services. As satellite planning systems are not subject to the SPA, they are not required to comply with SPP 1/03 (which addresses flooding). While evidence from the report suggests that, in practice, some consideration of flood risk is given by those assessing development applications, it is variable and not mandated. Potentially, this could result in less protection for vulnerable groups and essential services. The report makes recommendations to improve incorporation of flood risk in assessment processes.

Another issue raised was the *length of time* it took for various instruments to be due for revision – for example, 10 years for state planning policies and local planning schemes (pp. 99, 104). This means that there can be a significant time lag before amendments to address flood take effect. Conversely, temporary planning policies (which can bridge the gap while amending a planning scheme) were sometimes not sufficiently long. For example, a comprehensive flood study can take three years to achieve, yet a temporary planning scheme (which could temporarily prevent flood-prone land from being developed, pending flood study completion) will expire after 12 months (pp. 123–5).

Complexity of approval processes for amending planning schemes can be a barrier to timely amendment. One recommendation suggested that amendment of *existing* flood mapping should be reclassified as a minor amendment to a planning scheme rather than a major one, providing there is adequate public consultation. This would entail a more streamlined procedure, enabling timely incorporation of updated flood data into planning schemes (pp. 127–8). The Victorian Review presented similar time, cost and complexity issues for local governments wanting to amend planning schemes. The review recommends that the Victorian government should continue to consider automatic technical updates to planning schemes as risk information changes (p. 196).

'Competing pressures' can be an additional barrier to the amendment of planning schemes. The Victorian Review noted that population increase leads to pressures to develop into areas of higher risk, and that updated risk assessments can devalue property or make insurance more costly (pp. 195, 196). Hampered by a lack of record keeping, the Queensland Inquiry could not examine the root causes of the failure of Brisbane's planning scheme amendments to adequately reflect SPP 1/03 (p. 101).

The Victorian Review looks at *appropriate responsibilities* in the development approval process. According to the *Planning and Environment Act 1987* (Vic), planning permits in that state have to be referred to the relevant Catchment Management Authority (CMA) if the land is in a flood zone or overlay (flood information and mapping is thus a prerequisite to mandatory referral, though advice may also be sought without it). CMAs have the power to refuse development or impose conditions on development to make it more flood resistant. The Review sees this role of CMAs as appropriate, as they have technical expertise in flood management and a long-term understanding of flood risk implications. Furthermore, unlike councils, CMAs are not subject to competing pressures from interest groups and short-term economic gains such as rates increases. Current state policy in Victoria aims to remove this power from CMAs – not only removing their power to refuse development, but also removing their ability to impose conditions. Any advice they provide will become non-binding. The review finds that this will 'inevitably lead to poor flood planning outcomes', and recommends that CMAs retain their powers (pp. 192, 197). The Victorian government is not planning to make a formal response to the report. However, discussions at the 2012 Flood Management Association Conference revealed that all but three of the 93 recommendations had been accepted. One of those not accepted was the recommendation that CMAs retain their current

powers. This has been confirmed by the Victorian Minister for Police and Emergency Services (Ryan 2012).

Perhaps because of its restrictive terms of reference, the ENRC Inquiry report goes to some trouble to explain and justify the use of 'soft' flood mitigation measures such as development planning. It describes the history of flood management and the move away from infrastructure since the 1970s (pp. 25, 31):

> Despite considerable expenditure on structural works, the cost of flooding continued to grow as new development occurred on the floodplain. As a result, the importance and effectiveness of land use planning measures to control the growth of future flood damage became clear.' (ENRC Inquiry, p. 31)

Best-practice flood management processes currently used in Victoria include the *Emergency Management Manual Victoria* and the 1998 Victoria Flood Management Strategy. Both of these support a proactive prevention approach that sees risk elimination as the first step, which can be achieved through planning, regulation, legislation, land use controls, enforcement and structural works. To enable this, Victoria has good organisational arrangements in place that overcome the limitations of artificial administrative boundaries. Catchment Management Authorities (CMAs) have a number of roles (listed pp. 20–22) and involve local stakeholders via Floodplain Management Advisory Committees. CMA roles include overseeing floodplain management strategies, involvement in planning schemes, flood warning support, conservation of natural assets, managing flood infrastructure, and provision of monitoring and advice among others. CMAs are currently 'designated referral authorities for local government in implementing statutory planning provisions and for proposed construction of infrastructure assets on floodplains' under the *Planning and Environment Act 1987* and the *Water Act 1989*. This would appear to be a highly appropriate role for them to have, given their long-term perspective and whole-of-catchment view. Their value in providing a long-term perspective – particularly given climate change projections – was a point volunteered by a Victorian local government official during interviews. However, echoing the Victorian Review, the Inquiry report notes that the current government's stated policy is to remove these powers (pp. 21–2).

The report describes various land use and development controls and principles that are currently used in Victoria, but makes no recommendation about them (pp. 25–35, 40–2).

The reviews illustrate many issues with planning and development legislation in Australia, which result in *ad hoc* consideration of flood risk and implementation of mitigation measures. Moreover, one of Australia's best models for ensuring a more comprehensive approach to planning is under threat. These issues compromise adaptation to flooding, regardless of any increase in risk that comes with climate change. Many of the legislative gaps appear to increase the vulnerability of groups that are already vulnerable and compromise the resilience of essential infrastructure. While appropriate legislation and instruments already exist, they need to be amended to ensure more consistent consideration of flood in the development process. The *application* of legislation can also be improved through improved flood information, administrative processes, and clear and appropriate responsibilities and accountabilities.

Flood information

A prerequisite for the application of planning legislation and instruments that address flood is accurate flood information. Unless information exists about flood location, likelihood and severity, it is not possible to assess risk or put in place appropriate prevention or mitigation measures (see also on Legislative Framework section above). If the flood variables are expected to deviate due to climate change, it is important to

determine the extent to which flood information can incorporate climate change scenarios.

The main components of flood information are flood data, flood studies, flood modelling and flood mapping. The way that these fit together is described in the final Queensland Inquiry report (pp. 38–72), in the Brisbane Review (p. 36) and in the Victorian Review (pp. 57–63, 69–73, 192–7).

Flood studies analyse different rainfall scenarios and the stream flows expected to result from them (hydrology studies), as well as identifying flood behaviour in terms of flow rate, velocity, depth and extent (hydraulic studies). They can incorporate various data sources such as historical flood data, surveys, vegetation cover, land use, topography, riverbed mapping, sediment movement behaviour and data from weather stations. Flood studies usually analyse this data using flood models. Models can take account of numerous different variables, such as when and where rain falls in the catchment, the soil saturation level and dam levels, tides, predicted rain and even the effect of different dam operation strategies. The accuracy of modelling can be tested by comparing of modelling results with data from actual flood events.

Climate change is viewed as having the greatest uncertainty in flood studies. According to the Queensland Inquiry's expert panel of hydrologists and engineers, models that use Monte Carlo frameworks are the most useful for accommodating this, as they are better able to accommodate uncertainties (Recommendation 2.2; pp. 43, 45–6).

By converting stream flow values into water depth and extent, hydraulic models enable the development of flood maps. Flood maps also provide information on other aspects of flood behaviour, such as overland flow paths and consequences for an event of a given magnitude, such as roads being cut or levees overtopped. Once flood data have been converted in this way, the information is known as *flood intelligence*. These flood maps are used as a tool for assessing flood risk and applying land planning controls. Without them, legislation to regulate development in floodplains cannot be applied (Victorian Review, p. 194; Queensland Inquiry final report, p. 97).

In Victoria, 80% of floodplains are reportedly mapped for a 1 in 100 year event, but only 70% of these mapped areas are incorporated in planning schemes (pp. 194–5). In Queensland, most towns and cities are built on floodplains (p. 162). However, a recent review of planning schemes found that only 37% of schemes contained any flood-related mapping. Of these, only 23.6% were completed in accordance with the SPP 1/03 Guideline. The Inquiry concludes that this is 'a wholly inadequate level of flood mapping' (p. 62).

Since the 2010–11 floods, the Queensland Reconstruction Authority has produced maps for floodplains across the whole of Queensland, which councils can use as interim maps for planning schemes. The maps are intended to provide a basic level of mapping that can be refined by cross-referencing local information (p. 66).

There are many *barriers* to undertaking flood studies and flood mapping. Possibly the most significant issue is cost.

In Victoria, Catchment Management Authorities have a statutory obligation to provide flood information for councils to incorporate into their planning schemes. However, one CMA that was badly affected by flooding reported that no towns within its catchment had adequate flood mapping, the reason being a lack of a dedicated funding stream (p. 194).

Local government has the primary responsibility for producing flood studies in Queensland, as councils generally hold detailed local information and are the primary users. However, the inquiry found that generally local governments do not have

sufficient funds or technical resources to undertake flood studies (pp. 54–5, 62). A comprehensive flood study proposed for the Brisbane River catchment is expected to take three years to complete, and will cost in the 'low millions' (p. 42), which would be beyond the capacity of some councils. A further issue is that catchment boundaries appropriate for flood studies do not coincide with local government boundaries (p. 55).

The inquiry discussed the roles of other levels of government for provision of flood information. Through Geoscience Australia, the Commonwealth provides topographic data, which reduce costs involved in producing flood studies. The inquiry also sees a coordination role for state government involvement, including provision of funding and technical assistance and prioritisation of areas needing flood studies (p. 55). Currently, DERM reviews mapping contained in planning schemes to verify whether it has additional information to offer, but it does not review the appropriateness of modelling behind the maps due to resourcing constraints (p. 103).

The Victorian Review reports issues with *accuracy, completeness* and *currency* of flood information (p. 194). Flood maps can become outdated if there are landscape changes, such as new floodplain development, road or levee construction, farming system changes or major floods. These can all change future flood behaviour and cause existing flood information to become unreliable. However, there is no requirement in Victoria for periodic updating of flood information. The review suggests linking updates with landscape changes, rather than setting timeframes (p. 62). The Queensland Inquiry concurs, finding that flood mapping can rapidly become outdated, particularly in areas subject to high population growth (pp. 56, 193).

The Victorian Review recommends *mapping standards* to ensure consistent quality (p. 62). Much of the funding for flood mapping in that state is obtained through the Commonwealth government. Being externally funded, this makes it difficult to apply uniform standards. The Queensland Inquiry is also concerned with quality of information and recommends a review of existing guidelines for flood studies and flood maps (p. 72). Both reviews recommend the production of maps with a number of different flood scenarios, partly because floodplains mapped for a 1 in 100 year event are only useful for development planning and of no use during emergency response (Queensland Inquiry, p. 68; Victorian Review, p. 62).

More pertinent to the incorporation of climate change scenarios, both reviews argue that mapping for 1 in 100 year events is not sufficient from a development planning point of view, and events of both greater and lower likelihood need to be included as well, up to probable maximum flood (Queensland Inquiry, p. 63; Victorian Review, pp. 62–3, 197). The Victorian Review notes that recent flood mapping funded by the Victorian government includes multiple flood levels (p. 62). The Queensland Inquiry recommends that planning controls should be selected 'having regard to the likelihood, behaviour and consequences of the full range of possible floods, up to and including the probable maximum flood' (p. 63). The Inquiry provides a hierarchy of flood maps, rating as highest those that depict both likelihood and flood behaviour (pp. 63–8). When discussing likelihood mapping, the Inquiry does not acknowledge that stationarity is likely to cease with climate change, and that historical likelihood will no longer be accurate (p. 65). This is a notable omission that suggests a lack of comprehension about how climate change is expected to influence future flooding, outlined in Section 2 of this report. This will be discussed further in the 'defined flood event' section below and in Section 4.1.3, which discuss the use to which mapping information is put.

The Inquiry rates the Queensland Reconstruction Authority maps low in its flood mapping hierarchy, and questions their usefulness in a development planning context (pp. 67, 213–14). The main reason seems to be that the maps identify too large an area of flood-prone land, with no information on likelihood. The Inquiry argues that the large

area identified imposes a burden on development applicants. The Inquiry does not acknowledge that current likelihood values may cease to be valid as a result of climate change.

The Reconstruction Authority maps are based on satellite maps, with towns, gauging stations, contours, drainage data and the 2010–11 flood line superimposed. They also include soil (e.g. alluvium) and pre-clearance vegetation information to identify areas that have been inundated at some unknown point in history, adjusted using current contour information (p. 66). Arguably, the use of this geological information means that these maps provide a good representation of probable maximum flood levels. The Inquiry's reservations about the use of the Authority maps somewhat contradict its earlier enthusiasm to identify probable maximum flood levels (p. 63).

In his book on extreme events, Jonathan Nott (2006) looks at the application of the geological record for anticipating floods, noting that particularly in countries like Australia, 'short historical records may give a false impression of the nature of the flood hazard for a region'. This impacts on community vulnerability as it affects individual and community perceptions of risk and attitudes towards mitigating against it (pp. 1–16, 75). While the Authority maps are conservative, understanding past extreme flooding events could reduce our vulnerability to 'unprecedented' floods that are more likely under climate change. Using the Authority's maps in the absence of more detailed information would enable a precautionary approach to development that would assist climate change adaptation, loosening controls as more information comes to light rather than increasingly tightening them. Moreover, restricting development to conservative levels may provide an incentive to improve the knowledge base through funding flood studies.

Mapping enables *risk assessment* and the application of planning measures such as minimum floor levels and zoning to ensure that land use is compatible with the level of flood risk (Queensland Inquiry, p. 40). Risks are assessed in the context of a floodplain management plan that considers environmental, social and economic costs and benefits of different measures and acceptability of flood risk (p. 60). Both the Queensland and Victorian reviews found that resourcing for local governments in terms of financial and technical ability compromised their ability to undertake risk assessment. They found that greater support was needed from state government, which could also provide assistance by developing standards and providing coordination (Queensland Inquiry, p. 60; Victorian Review, p. 39).

All reviews, including the Natural Disaster Insurance Review (NDIR), recommend that flood risk information should be publicly available to improve risk assessment and development outcomes (Brisbane Review, p. 36; NDIR, pp. 67–70; Queensland Inquiry, pp. 69–71). The Victorian Review is somewhat more cautious, noting that land values may decrease, but otherwise strongly supports improved community information about local flood risks in the context of improving emergency response (Victorian Review, p. 85, 196, 217–20). The interim Queensland Inquiry notes that a statewide register of Queensland's natural hazards is currently being developed to ensure a risk-management approach to disasters (pp. 116–17). The final Queensland Inquiry report (pp. 58–9) and the NDIR (p. 69) both recommend a central repository for flood risk information. The value of improved risk information is discussed further in the community resilience section, below.

Issues of *liability* were found to be a significant barrier to the provision of flood risk information and its incorporation into planning schemes by local government (Victorian Review, p. 196; Queensland Inquiry final report, pp. 128–32; NDIR, p. 70). Inclusion of climate change information was a particular issue raised in both the Queensland and Victorian Reviews. The Queensland Inquiry reported that councils are exposed to compensation claims if land is 'down-zoned', subjecting it to flood controls and reducing

land value. They are also liable for losses if they provide flood advice, act or fail to act in respect to flood-prone land (Queensland Inquiry final report, p. 128). This issue is also identified by Gibbs and Hill, who note that some states – such as Queensland – have greater legal provision for compensation than others for councils wishing to apply development controls (Gibbs & Hill 2011).

The NDIR finds that there is a potential liability for the quality and accuracy of flood information (p. 70). In one case reported by the Queensland Inquiry, a council decided not to provide any information on historic or current flooding unless an application was made under Freedom of Information (FoI) legislation (Queensland Inquiry, p. 130). A recent paper by Eburn and Handmer (2012) finds that the liability risk of providing flood risk information is vastly overstated, and there are 'no cases where anyone has successfully sued a council for releasing up to date, accurate hazard information'. Rather, councils face liability for not supplying information about known risks (Eburn and Handmer 2012).

The Queensland Inquiry finds it is important that councils not be inhibited by statutory liability to compensation from adopting appropriate regulations and providing information. It makes no formal recommendation on these issues, but discusses NSW legislation as a possible solution. Statutory immunity is provided by section 733 of the *Local Government Act 1993* (NSW) (recently amended to include climate change information). The application of this legislation is currently being investigated by the Queensland government. Granting indemnities for information provided in good faith is similarly recommended by the NDIR (p. 70).

While not discussed in the Victorian Review, water authorities in that state are liable to compensate people who incur a loss due to the performance of water authority functions under the terms of the *Water Act 1989* (Vic). This potentially could include failure to take climate change risks into account. The authors view this as positive, as it could encourage reassessment of the adequacy of existing planning controls (Godden & Kung 2011).

Defined flood event

Adopting a defined flood event (DFE) or flood level is a key planning tool in both Queensland and Victoria. According to the Queensland Inquiry, state planning instrument SPP 1/03, which addresses flood risk, cannot be applied unless planning schemes adopt a DFE. Generally, a 1 in 100 year event is adopted (Queensland Inquiry final report, pp. 63, 147; Victorian Review, p. 193). This level is not a compulsory requirement in Queensland, but is included in Victoria's *Water Act 1989* (Vic) as a minimum default that applies to catchment management authorities. The defined flood event is based on an historic flood and it is used to determine the level of flood hazard for a location and any development controls that need to be applied to mitigate risk. For example, it can be used to prevent incompatible development from being sited in an area of flood risk, or it can apply controls such as the height of habitable floor levels. For both states, habitable floor levels are usually set at the 1 in 100 year event level with an additional freeboard of between 300 and 500 mm (Victorian Review, p. 193; Queensland Inquiry, p. 147).

Brisbane bases its planning scheme on peak flood levels reached during the 1974 floods. From this, it has determined habitable floor height for residential properties situated along the Brisbane River as defined flood level (DFL) + 500 mm freeboard (Brisbane Review, pp. 17–18, 56–8). According to the Brisbane Review, the Brisbane DFL based on 1974 flood levels is actually more conservative than a 1 in 100 year event. However, the final report of the Queensland Inquiry reveals that there has been ongoing debate and study into what the 1 in 100 flood level actually is for Brisbane, with

some studies suggesting the level should be considerably higher (pp. 48–51). A comprehensive flood study for Brisbane is proposed, which may resolve this issue (Queensland Inquiry, pp. 41–5).

During the 2011 floods, 23.7% of the flood-affected area of the city was built above the DFL (p. 57). While most flood-affected properties (wholly or partially inundated) were in older parts of the city, 10.5% were in suburbs predominantly developed after 1978 (when DFL came into play). It appears from this that the DFL was inadequate to cope with the 2011 flood. It is probable that exemptions to planning instruments may have influenced the effectiveness of the DFL planning tool (see Legislative Framework section above). The report makes no mention of compliance with the post-1978 DFL.

One recommendation to come out of the Brisbane Review is a lifting of the DFL to 2011 flood levels. Resetting the DFL to 2011 flood levels seems reasonable as an interim measure. However, this recommendation does not allow for the possibility of a future 'multiple event' scenario. The review notes that the 1974 and 2011 flood events had different causes. In the 1974 flood, local rain over Brisbane caused extensive flash flooding, and the Brisbane River caused secondary flooding. In the more severe 2011 event, there was little rainfall over Brisbane itself. A revised DFL to 2011 flood levels would not allow for a possible multiplication effect if flash flooding caused by rainfall over Brisbane coincided with the river flood caused by rainfall higher in the catchment.

All reviews suggest that it is important to move away from a single defined flood level for development planning. The Brisbane Review endorses a Flood Taskforce recommendation that flooding up to the most extreme event should be considered. It supports a risk-management approach in line with the National Flood Risk Advisory Group (NFRAG) guidelines (p. 57). The Queensland Inquiry similarly finds that the focus on a single defined flood event is insufficient:

> Restricting development within the extent of the [1 in 100 year] flood will manage a portion of the risk, but it does not deal with the risk of floods that are less frequent, but more severe, or those that will occur more often, but with less damaging consequences. Instead, the various areas to which planning controls apply should be selected having regard to the likelihood, behaviour and consequences of the full range of possible floods, up to and including the probable maximum flood. (Queensland Inquiry final report, p. 63)

The Inquiry found that residential housing needed to be located in low-hazard areas, as this use was most vulnerable to flood in terms of loss of life, injury and property damage. However, at one point the Queensland Inquiry contemplates accepting lower habitable floor levels for residential areas – for example, at the 1 in 50 year flood level – depending on the community's willingness to accept risk (pp. 147–8). The question of *who bears the cost of that risk* – be it insurance companies, charities, taxpayers or future generations – is not discussed by the Inquiry. A recent decision by Suncorp to not insure entire towns for flood risk unless mitigation measures are undertaken indicates that insurance companies at least are not willing to bear that cost (Jabour 2012). Accepting lower floor levels seems maladaptive if lesser floods are expected to increase in frequency and if the number of large floods is expected to increase (a possibility the Inquiry does not acknowledge when discussing this issue).

The Victorian Review, cross-referencing findings in the Netherlands and the United Kingdom, finds that the 1 in 100 year event level is insufficient, particularly for community facilities and essential services. It recommends amending legislation or policy to increase floor levels for this type of development if siting in flood-prone areas is unavoidable (p. 197).

Considering scenarios outside the usual 1 in 100 year event would help to allow for greater weather variability as a result of climate change. A current review of SPP 1/03 is considering the determination of DFE, including when it is appropriate to select a greater or less than 1 in 100 year flood (p. 99). However, it is concerning that none of the flood reviews appears to contemplate the possibility that weather patterns under climate change are unlikely to remain stationary, and thus likelihood values may change. A particularly notable omission is in the Queensland Inquiry's discussion on flood mapping (pp. 62–7), even though this issue is well recognised by water resource management professionals in public utilities such as Melbourne Water as well as by researchers (Milly et al. 2008; Pedruco & Watkinson 2010; Rahman et al. 2010; Godden & Kung 2011).

Despite the lack of integration of this issue into its report, the Queensland Inquiry does include some instances of climate change being considered. The Inquiry's expert panel recommended that climate change risks be included in the Brisbane flood study (p. 45). The Inquiry also received evidence from North Burnett Regional Council about a commissioned flood study aiming to incorporate climate change into its flood risk management framework and its DFE. However, the council reportedly has reservations about adopting a climate change factor of 20% and is looking at how best to present this information in its planning scheme (p. 130). The results of the North Burnett study are published in the Queensland Inland Flood Review. It suggests a climate change factor of 5% per degree of global warming be applied to rainfall depths and that local governments use the following projections in their flood studies, pending update of the Australian Rainfall and Runoff handbook: 2ºC by 2050, 3ºC by 2070, 4ºC by 2100 (Queensland Government 2010). This climate change factor is to be applied statewide (QRA 2012, p. 45).

Current 'best practice' in hydrology/engineering in terms of dealing with uncertain futures with respect to drought or flood risk is to (1) calculate existing risk (i.e. under a stationarity assumption); (2) quantify how that risk is elevated or suppressed by different natural climate drivers (e.g. different epochs of the ENSO cycle); and then (3) quantify how those drivers and associated impacts might change in the future under anthropogenic climate change and from there determine the possible changes to flood risk. In this way, the approach focuses on both natural variability and potential anthropogenic climate change, given that both hydroclimatic drivers need to be considered together. Engineer Australia's Australian Rainfall and Runoff (AR&R) is the de facto standard for flood estimation in Australia and is currently undergoing extensive review. Many of the issues identified in this report are being addressed in the AR&R review process, such as updates to design flood estimates (e.g. 1:100, 1:50, 1:20, etc.), dealing with climate change in flood estimates and modelling, and professional training.

Adaptation measures to non-stationarity have been suggested by some authors. Milly et al. (2008) propose higher resolution (more localised) modelling incorporating a wide range of information, coupled with improved information transfer in both directions between water managers and climate scientists. This measure would make information more locally relevant and decrease uncertainty. The need to downscale climate change flood information to the catchment level is an issue that has been identified by this project's end-users committee and it has also been identified as a key issue in a recent Productivity Commission report on barriers to effective climate change adaptation (Productivity Commission 2012). The reason why information on the effect of climate change needs to be localised is that the degree to which flooding is worsened will vary from catchment to catchment. To illustrate this, depending on catchment characteristics (e.g. landscape features that constrict the passage of water downstream, or a wide floodplain where water can spread versus a narrow floodplain), a 1 in 100 year flood can have very different consequences. In some catchments, the difference between a 1 in 10

year flood and a 1 in 100 year flood can be just a few centimetres in depth (though it may have greater extent), whereas for other catchments the difference may be many metres. This illustrates the dangers of relying on a planning standard, such as the 1 in 100 year event standard, rather than identifying flood consequences based on a localised flood study (Smith 1998). Supported by catchment-level information, adaptation to climate change needs to be sensitive to consequence and not just likelihood.

Attempts are being made to make climate change information locally relevant. A recent joint project undertaken by the Queensland Local Government Association and state government agencies provided a climate change factor for increased rainfall intensity that can be incorporated into flood studies (Department of Environment and Resource Management & Department of Infrastructure and Planning 2010).

Case study:
Development controls in flood prone areas, Wagga Wagga

The city of Wagga Wagga on the Murrumbidgee River in NSW was first settled in the 1840s. The low-lying northern floodplain was the first area to be inhabited, and became the site of modern North Wagga Wagga. The flood-prone nature of the settlement soon became obvious. Major floods occurred in 1844, 1852, 1853 and 1870. Between 1886 (when official gauge data started being collected) and 2005, 76 significant floods were recorded.

In the 1960s, following a period of successive floods in the 1950s, a blanket ban was placed on development in North Wagga, while a 1 in 100 year levee was built to protect Central Wagga. This resulted in property values in Central Wagga increasing while North Wagga values decreased. Despite the ban, 20 years later there had been no appreciable decrease in the number of residences in North Wagga. This was an inequitable solution which did nothing to reduce the flood risks for North Wagga residents.

Provisions were amended in 1987 as part of a compromise negotiated by council with the NSW Department of Planning. As part of this agreement, a 1 in 20 year levee was built in 1991 to protect North Wagga against most frequent flooding. Under the revised development provisions, new development continues to be prohibited. However, property is allowed to be rebuilt if it is destroyed by flood, provided it meets new flood resilience standards in terms of strength and height. For residential properties, floor levels are required to be at the 1 in 100 year flood level plus 500 mm freeboard. Thus rebuild height provides significantly better protection for property than the 1 in 20 year levee, which could potentially be rendered redundant in the future. Limited increase of floor space of up to $50m^2$ at the existing level is permitted using flood-compatible materials.

The Council ensures the availability of flood risk information by including details on the property's S149 certificate. Retrofitting of flood-prone properties by means such as house raising is also encouraged, and development application fees are not charged. Through this combination of measures, it is hoped that the risks of flooding for North Wagga residents will be reduced over time.

Sources: Askew (2009); Wagga Wagga City Council (2010); Adrian Stander, Senior Town Planner, Wagga Wagga City Council.

Other adaptation measures to address non-stationarity have been suggested by Lee Godden and Anthony Kung. Their paper on regulatory and planning law suggests that measures in these areas could do much to encourage autonomous and private adaptation. They recommend use of incentives and community engagement. An example of the use of incentives is given in the final Queensland Inquiry report, where a lower level of development assessment is required for certain types of non-residential development applications to enable transition of existing residential areas to lower impact uses (pp. 146–7). Regarding planning controls, Godden and Kung recommend a reassessment of 'whether the 1 in 100 flood event datum should remain the standard basis for flood risk demarcation in water law and relevant planning laws'. Their research suggests the Victorian coastal strategic planning framework, including the use of vulnerability assessments and mandatory planning for sea level rise of 0.8 metres by 2100, has resulted in a more strategic regulatory approach (Godden & Kung 2011).

4.1.3 Improved materials and design

While it is preferable to avoid siting development in areas of flood risk, this is not always possible to achieve (Queensland Inquiry final report, pp. 223, 245). Improved materials and design can be used to improve flood resilience, and can significantly reduce damages and enable rapid clean-up and recovery. This is a useful adaptation measure for climate change, as it can mitigate more frequent small flooding as well as extreme flood events. Some measures can be retrofitted to existing properties, which could usefully be applied to properties affected by changing patterns of flood extent and location.

Building codes and standards

National building standards are set through the Building Code of Australia. Currently, there are no national standards for building in flood-prone areas, though the Australian Building Codes Board is in the process of developing one for residential development (Victorian Review, p. 193; Queensland Inquiry, p. 212).

As well as national standards, building construction in Victoria is regulated by the *Building Act 1993* (Vic) and Building Regulations 2006 (Vic), of which one, regulation 802, relates to flood. However, the only design aspect that can be specified through this regulation is floor height. The regulation does not include flood-resilient materials or other design features.

Queensland's state building standards are regulated by the Queensland Development Code and Building Regulation 2006 (Qld). The Code does not include regulation of building construction in areas at risk of flooding. The government is drafting a new mandatory part to the code, Part 3.5: 'Construction of Buildings in Flood Hazard Areas', based on the new draft national standard. This would cover design, but not water-resistant materials. The latter may form a non-mandatory provision (pp. 211–13).

The Queensland Inquiry finds the requirement of Part 3.5 to establish a defined flood level may place an unreasonable financial burden on people wishing to develop flood-prone land. It recommends restricting application of Part 3.5 to situations where councils have already carried out the required flood analysis (pp. 213–15). This seems at odds with an earlier Queensland Inquiry recommendation that applicants should be responsible for supplying information to enable assessment of flood risk for areas where likelihood of flooding is unknown (p. 121). Whether it is advisable to facilitate development of designated a flood hazard land in this way is a fundamental issue. A more precautionary approach would be to require that all land that has a potential flood risk be subject to site-based flood studies before development approval is given for, regardless of whether such information already exists or who should bear the cost.

As per development planning legislation, building codes only apply if flood hazard areas have been designated, although Victoria has more flexibility in that the local planning scheme is not the only mechanism by which flood-prone land can be identified (Victorian Review pp. 193, 196; Queensland Inquiry, p. 213).

The Victorian Review strongly supports the adoption of construction standards for flood-resistant materials and design (pp. 193, 197). However, the Queensland Inquiry is cautious about the additional costs and affordability implications of adopting prescribed mitigation measures (pp. 211, 216). While not discussed in the reviews, incentives such as improved insurance premium affordability for properties that have implemented mitigation measures could encourage improved construction standards (NDIR, p. 20).

The Queensland Inquiry looked at the suitability of various different types of development on flood-prone land, as well as building materials and design that could increase their flood resistance. Various examples of use of flood-resistant material, design and retrofitting are described in the final report of the Queensland Inquiry, covering buildings (pp. 150, 211) and infrastructure (pp. 160–1, 244). Since the 2011 floods, the Queensland government has also produced various guides that include retrofitting and use of materials and design to ensure better flood resistance (Queensland Reconstruction Authority 2011a, 2011b; Queensland Government 2011d).

A particular issue during the floods was the vulnerability of high-rise buildings with basements. One reason for this vulnerability was that machinery for building services such as lifts, lighting, ventilation and emergency electricity generators is often located in basements. This meant that some buildings were unable to be occupied for long periods after the flood. Basements were also found to be costly to clean up after the event (Brisbane Review, pp. 58, 63). At the time the Brisbane Review was written, the protection of these services was not supported by building regulations, though subsequent to the flood, council decided to develop a new Code for Basements and Building Services. The review proposes flood-resilient design and the use of backflow devices to prevent basement flooding (p. 63). The final Queensland Inquiry also acknowledges problems with basements, and discusses a number of material and design features that could be incorporated to increase resilience as well as amendments to relevant guidelines and processes (pp. 234–5, 246–8).

Commercial buildings are often more structurally robust, and commercial users may be willing to establish in flood prone areas because of commercial benefits such as cheaper rents. It can sometimes be easier for commercial users to refurbish in order to increase flood resilience, though depending on the type of business, this was not always the case (pp. 151–2).

There are issues with siting industrial uses on flood-prone land, as this often involves the manufacture and storage of hazardous materials. The Inquiry found that large amounts of hazardous material were discharged on to land and into waterways during the floods, signalling inadequate consideration of flood risk. Siting of such facilities out of flood zones was seen as impractical, because confining such enterprises to more valuable land would increase manufacturing costs and impact on competitiveness. Design options include storing goods in impervious containers that are unable to be shifted by floodwaters, or storing and manufacturing on higher levels within a building. Solutions that required moving hazardous materials prior to flooding were not seen as sufficient on their own, as they are dependent on warning time, evacuation routes that can be cut and measures relying on human intervention that can be unreliable (pp. 153–8).

Telecommunications

Maintaining telecommunications is very important during disasters to exchange information and coordinate response, and it is important to ensure they are able to continue to function during such events (Queensland Inquiry final report, pp. 249–52). Discussions relating to telecommunications in the Victorian and Brisbane Reviews do not address siting or design, though all reviews reinforce the importance of telecommunications during emergency response. See also 'essential services' in the emergency response section.

Telecommunications infrastructure that is 'low impact', temporary or defence-related is exempt from state and territory planning laws according to Commonwealth legislation, the *Telecommunications Act 1997* and the Telecommunications Code of Practice 1997. The Code does not include consideration of flood risk when selecting a site.

Queensland's SPP 1/03 Guideline provides advice on the siting of telecommunications infrastructure to address flood risk. However, as the guideline is non-binding, local council codes do not always reflect this (e.g. Brisbane City Council's telecommunication tower code does not take account of flood risk). The Queensland Inquiry notes that the siting of telecommunications facilities in areas of low flood risk can be compromised by the need to minimise impact on communities (e.g. visual impact).

The Inquiry lists some design and siting measures undertaken by telecommunications carriers to minimise flood risk when they are built on floodplains, including the use of elevated platforms (p. 251).

Electricity

There were significant issues with electricity supply during the floods in both Queensland and Victoria, as well as extensive damage to infrastructure. This is a particular concern, given that emergency response is highly reliant on the continuation of electricity services (see 'essential infrastructure' in the emergency response section).

In Queensland, some electricity infrastructure is exempt development, and is not subject to planning controls (Queensland Inquiry final report, p. 241). Conflict with other planning priorities can also compromise siting of electricity assets (p. 242). Measures that can help to address this include appropriate design measures, revision of industry standards, inclusion of assessment criteria in model flood planning controls and legislative amendment (pp. 242–9).

When floods threaten, electricity services are often disconnected as a pre-emptive measure to prevent danger to people from electric shock and to prevent costly damage to infrastructure. This can cut electricity supply to people not affected by flooding if services pass through flood-affected areas. The Inquiry suggests that installation of connection points for generators could reduce this problem (p. 246).

Stormwater

Urban drainage is likely to be impacted by climate change, as it was designed under the assumption that climate was relatively stable. Drainage systems may not be able to cope with increased magnitude of floods and may also sustain damage more frequently, increasing recovery costs. The following is an extract from a report by Melbourne Water:

> This change in rainfall intensities may have significant implications on future planning management and infrastructure. For instance drainage infrastructure designed to the 1 in 5 year standard may be overwhelmed on average at least once every 3 years by 2030 in smaller urban catchments. (Pedruco and Watkinson 2010, p. 12)

Increasing rainfall intensity is only one factor affecting the capacity of drainage infrastructure. For coastal settlements, rising sea levels will be an added complication if high tides cause storm outlets to submerge (Queensland Inquiry final report, p. 237). Another factor is population density, which has increased beyond that originally anticipated when stormwater infrastructure was built (p. 236). As populations are projected to increase, this will continue to be an issue.

The Queensland Inquiry provides details about how stormwater systems work, with underground pipe systems generally designed to cope with frequent minor storms with an average recurrence interval of between two and 10 years. Storms of greater magnitude are accommodated via overland flow paths (p. 232). The report notes that appropriate dual-function uses for flow paths include roads (following overland flow paths rather than transversing them) and parkland. Inappropriate development in the middle of overland flow paths can impede drainage, and the Inquiry recommends that for urban areas, these flow paths be mapped so they can be considered in relation to new development. However, there are cost and expertise issues for some councils (pp. 233–4).

Backflow prevention devices are discussed in the Brisbane Review as an option to address water backing up through the piped system from outlets along tidal reaches of the river, causing flooding. The report does not recommend its use in stormwater drains, due to maintenance issues (pp. 61–2, 67).

The final Queensland Inquiry report also studied backflow prevention. In the context of basements, it supported improved siting and design of utilities within buildings, but was cautious about the use of backflow prevention devices in basements (pp. 234-5). Backflow prevention devices were seen as an option for stormwater drains at high risk of flooding, but the report agreed with the Brisbane Review regarding ongoing maintenance issues, stating that use of backflow prevention devices should be contingent on risk assessment (p. 239). Other options included higher habitable floor levels and construction of stormwater outlets at higher levels (noting that, as systems are gravity based, there were limitations to this latter option).

The final Queensland Inquiry also examines the role of detention basins for managing stormwater (pp. 234, 597–9). This is covered in more detail in Section 4.1.5.

Sewerage system

Sewage backs up when the sewerage system is overwhelmed due to the infiltration of stormwater into the sewerage system (which can happen through various means, such as illegal stormwater connections, pipe joints or through openings such as overflow relief gully grates). This can cause the reflux of sewage into properties and the inundation of sewerage infrastructure at pump stations, causing large damage bills and delayed recovery (pp. 220–30). Overflow relief structures designed to discharge untreated sewage into waterways in emergencies cannot be relied upon in extreme events, as these outlets can be submerged, causing increased pressure in the pipe network and backflow (p. 227).

The report recognised that it was difficult to alter the siting of sewerage plants, as they are mostly gravity driven and positioned close to rivers. Improvements therefore need to focus on design, such as submersible electrical components and raising the level of vulnerable equipment. To reduce infiltration of stormwater into the system, recommendations include the trial of overflow relief gully grate caps, sealing sewerage network pipes to prevent stormwater from entering.

Backflow prevention and pressurised pipes were recommended as a mandatory design measure for the sewerage systems of houses in flood hazard areas, due to the significant damage caused to some properties when sewage backed up through toilet

and showers. As ongoing maintenance of these devices would be the responsibility of the homeowner, the Inquiry also recommends that guidance material be developed (p. 228). Amendment of relevant design standards is also suggested in the report, to ensure flood resilience is considered (pp. 213, 225). Such design measures would increase the resilience of properties to climate change flooding, including minor floods of greater frequency. Regarding illegal stormwater connections, the Inquiry suggests the incorporation of redundancy in design to help accommodate it, coupled with public awareness, improved investigation and enforcement (pp. 228–30).

Transport

The final Queensland Inquiry report examines design improvements for transport infrastructure. These are mainly discussed in the context of repair and rebuild rather than initial development design. Measures include raising the height of access routes, such as bridges and roads. In the case of roads and railways, the design and siting of culverts is important to ensure flow paths for floods are not impeded, preventing natural drainage (p. 231).

Raising the height of roads is an extremely expensive option that competes for funding with other road improvement priorities such as road safety and reducing congestion (pp. 253–4). The Brisbane City Council's Growth Planning Strategy 'envisages growth centres and transport corridors outside potentially flood affected areas' (Brisbane Review, p. 59). Depending on how flood-affected areas are defined and identified, this could be a much more cost-effective approach than rebuild and repair.

4.1.4 Betterment

Betterment is a term used to describe the replacement of damaged infrastructure to improved standards, enhancing its ability to withstand future disasters. The rebuilding of infrastructure addresses recovery as well as prevention. In this report, betterment is included as a prevention measure, as it is more than simple replacement.

While betterment may increase short-term recovery costs, substantial long-term savings can be made by obviating the need to replace the same infrastructure multiple times in the future.

A study of the impacts of climate change undertaken by Melbourne Water (discussed in the Stormwater section above) points out that cities and infrastructure have been developed under the assumption that climate is relatively stable or stationary. Major floods are likely to happen more frequently as a result of climate change, escalating repair and replacement costs if infrastructure is not upgraded.

The Victorian Review highlights a need for betterment, particularly if infrastructure is inadequate or likely to be damaged again in future floods. Current federal grants processes technically allow for betterment, but they are complex and time-consuming, requiring cost-benefit analyses and pre-approval before works can be started. According to the Victorian Review, 'no betterment projects have ever been approved' by the Commonwealth under its Natural Disaster Relief and Recovery Arrangements grants process (p. 211). Arrangements for facilitating betterment will need to be revised, particularly in view of the high-level support it receives from the COAG National Strategy for Disaster Resilience. This strategy lists as a priority outcome:

> Following a disaster, the appropriateness of rebuilding in the same location, or rebuilding to a more resilient standard to reduce future risks, is adequately considered by authorities and individuals. (COAG 2011, p. 12)

Betterment is not explicitly covered in the interim Queensland Inquiry report, although it does discuss the upgrading of undamaged but inadequate bridges. As an example, the bridge of Youngs Crossing was closed during each of the 18 flood events that occurred between October 2010 and March 2011. This caused great disruption and community resentment about water releases from the North Pine dam upstream. Raising the bridge height to cope with flows up to 300 m^3/s is suggested as a possible solution, contingent on the outcomes of a cost-benefit analysis (p. 93).

The final Queensland Inquiry report covers upgrade more comprehensively, including discussions of stormwater, roads and other infrastructure. Cost is cited as a major impediment (pp. 232, 254).

The final report expands on the issue of raising bridges first raised in the interim report. Raising bridges can have the additional benefit of providing greater flexibility to dam managers to release floodwaters following a flood event. If floodwaters recede too quickly, it can cause significant loss of agricultural land due to slumping (see Section 4.1.6). However, dam managers currently are obliged to reduce water levels as quickly as practicable so as not to prolong inundation of bridges and the inconvenience that results (Queensland Inquiry final report, pp. 578, 588–90). Increasing the height of bridges could therefore not only improve access during flooding but also result in reduced bank erosion.

The Brisbane Review reports that significant damage was sustained by Brisbane's riverine infrastructure, including pontoons, jetties, the floating Riverwalk, ferry terminals, and river walls and banks. Infrastructure of this kind has a replacement cycle, so it would be unrealistic and economically unviable for infrastructure to be required to withstand the worst possible flood. 'Each item should be designed to a standard that is appropriate to their importance and normal "life cycle".' (Brisbane Review, p. 67). The council commissioned an engineering assessment of riverine assets, which may lead to design improvements. The final Queensland Inquiry report also makes a number of recommendations for rebuilding Brisbane's river infrastructure to improved standards (pp. 159–61).

Related to the upgrading of infrastructure is the rebuilding or retrofitting of dwellings and commercial buildings to increase their ability to withstand future flooding. The Brisbane Review reports that it can be difficult for local councils to influence rebuilding to improved standards. Brisbane's development planning is controlled by various state government legislation, such as the *Sustainable Planning Act 2009* (Qld) (SPA) and the *Building Act 1975* (Qld). Other pieces of legislation include the Building Code of Australia and the Queensland Development Code. The SPA empowers the council to make local planning instruments. However, the City Plan has limitations:

> A rebuild or repair of a dwelling house to 'as was' standard and design prior to flood damage requires neither development approval or building approval, provided that the 'as was' was itself lawful.
>
> Similarly, regulating the retro-fitting of commercial buildings with flood-proof design measures will be difficult from a Council perspective as the planning scheme primarily deals with triggers for new development (or changes to the intensity and scale of uses). These restrictions make it extremely difficult to channel modification of existing development through the Council approvals process. (Brisbane Review, p. 55)

The Brisbane Review concludes that, 'whilst Council can take the lead on town planning reforms, many of the major planning issues can only be addressed comprehensively through changes to legislation, policies and codes at state government level'. While discussing this issue in the text, the Review does not include it in its recommendations.

There are a number of barriers to betterment, including legislation and resourcing mechanisms. However, rebuilding to pre-existing standards constitutes a missed adaptation opportunity that is likely to be costly in the long term.

4.1.5 Engineering solutions

The reviews, and primarily the Brisbane Review, touch on a number of engineering solutions to floods, including backflow prevention (including river barriers, floodgates and one-way valves), levees and flood walls, dredging and flood-mitigation storages. While it lists these measures, the Brisbane Review only examines backflow prevention in detail. Levees are touched on by all reviews and flood-mitigation storages (detention basins) are covered primarily by the Queensland Inquiry. In general, all reviews are cautious about these measures in terms of cost, maintenance and efficacy, except in specific circumstances.

Levees

The extent of levee use in Australia is hard to gauge due to a lack of regulation in some places. Victoria's Department of Sustainability and Environment (DSE) reports a minimum 4000 km of levees in Victoria, including 50 km of urban levees with clear management arrangements (and another 50 km of older urban levees without). Most modern urban levees are built to withstand a 1 in 100 year flood. Victoria also has about 3920 km of rural levees. Of these, about 820 km were built – generally to the 1 in 20 or 1 in 30 year flood level – with government assistance. The remainder were privately built on private land. Most privately built rural levees were constructed prior to development controls being in place, often to a very poor standard. Private levee height is arbitrary (Parliament of Victoria 2012, pp. 55, 57, 61; State Government Victoria 2012, pp. 20, 25).

Queensland Inquiry reports do not provide figures to indicate the extent of levee building in Queensland. However, reports observe that irrigation channels often serve as *de facto* levee banks. The true extent of levees could be under-estimated if such levee-like structures are not also taken into account.

Levee regulation. Levee regulation varies according to state. In Victoria, the first state levees were built in 1895. Currently, most local government planning schemes in that state have controls on earthworks, with requirements to obtain a permit, which has reduced the amount of levee building on private land. However, DSE reports that flood zones and overlays are inadequate in some planning schemes. Enforcement is also an issue, and some levees are built without approval, while processes to remove illegal levees are complex and time-consuming (State Government Victoria 2012, pp. 19–30). Urban levees are regulated through the *Water Act 1989*.

Victoria has a number of measures in place on a state level to assist in the regulation of levees, including technical guidelines for levees, Levee Design, Construction and Maintenance, produced in 2002. It also has a Flood Management Strategy that provides a statewide framework for flood management and a Victoria Flood Database, which includes (incomplete) information on levee location and audit of high-priority levees. Significant information gaps remain, particularly for rural levees and levees constructed as part of emergency response. Information is needed on levee ownership, height and condition, and responsibility for maintenance. Clarity is also needed about responsibility for temporary levee removal.

The final Queensland Inquiry report raises some serious issues about the management of levees in that state (pp. 168–72). It notes widespread failure of local governments to regulate levees, as this is not a compulsory requirement of planning schemes. In some

areas, property owners have free rein to construct levees and there are claims that these have worsened flooding elsewhere.

A lack of technical expertise and financial resources is partly to blame for failures to regulate levees in Queensland. In one instance, two shire councils formed a floodplain board with the power to assess levees on a catchment scale. Two years later, the board dissolved itself due to lack of technical capability and resources, arguing that the magnitude of the issues and the multi-million dollar interests involved made this task more appropriate for state and national governments.

The final Queensland Inquiry stresses a need to regulate levees consistently; they need to be 'assessable development' requiring a development permit, and catchment-wide implications of levee proposals need to be assessed. However, as is the case with other development planning (see Section 4.1.2), local decisions not to grant permits can be overruled at the state level, as was the case with the Ensham mine levees. Consistent levee assessment processes and criteria need to be developed, and local governments need to be resourced to enable them to do this. The recommendations include consideration of other measures to mitigate proposed levees, such as emergency management and land planning. While acknowledging the considerable adverse impacts that levees can have, the Inquiry does not suggest processes to consider cost-effective alternative solutions to levees.

Maintenance. Private ownership of levees and a lack of clear responsibility for maintenance reduce the reliability of levee protection. Private levees are often hastily and poorly constructed prior to or following a flood, and are liable to failure. Lack of defined ownership and responsibility for the maintenance of rural levees on public land results in their deterioration and low reliability during flood events (Parliament of Victoria 2012, p. 51). Liability is also an issue, with concerns that any agency that takes responsibility for maintaining a levee will be liable to prosecution if the levee fails. The Inquiry into Flood Mitigation Infrastructure in Victoria (pp. 47–97, 145–56) recommends numerous measures for improving levee management, including recommendations relating to:

- identifying priority and non-priority levees on public land by assessing their benefit to cost ratio and regional benefit, with priority levees being subject to a water management scheme under the *Water Act 1989*
- revision of the Victoria Flood Management Strategy and the *Water Act 1989* to clarify roles and responsibilities for levee ownership and management responsibilities, with ownership and maintenance to be defined by the beneficiary pays principle
- maintenance funding arrangements (e.g. through rating of beneficiaries)
- revision of technical guidelines on levee design, construction and maintenance
- removal of non-priority levees built on public land, where economic benefits are low
- improved processes to remove illegally built levees on private land
- allowing low-priority levees on public land to disintegrate where beneficiaries are unwilling to fund maintenance, and communication of such decisions to those affected
- access and conditions for maintenance of levees sited on public or private land
- streamlining permits for maintenance works and rural ring levee construction
- continuing audit of both public and private levee systems to feed into the Victoria Flood Database, with provisions for annual levee inspection and maintenance schedules

- inclusion of existing levees in emergency plans, to be informed by mapping and modelling; with agreed activities in plans also needing to identify what is the appropriate use of temporary levees
- ownership of decommissioned irrigation channels, and ascertaining when it is appropriate to construct roads with a dual purpose to serve as levees
- cross-border coordination of levees along the Murray River
- protection of public authorities from legal liability for levee works, providing work is conducted according to standards, is in the public interest and is not negligent.

Appropriate use of levees. Levees are an extremely expensive flood-management option, and have ongoing maintenance and management implications (BTRE 2002). This means the benefits of constructing levees have to be clear.

The Brisbane Review suggests levees are a solution most appropriate to protecting specific key assets such as the Brisbane Markets, and areas with high population density (pp. 60–2). The interim Queensland Inquiry also discusses the Brisbane Markets in its chapter on essential services, noting its importance with regard to food supply. With the Markets currently situated on a low-lying 77 ha site, the construction of levees is only one option suggested by the Queensland Inquiry to protect the site. Raising the floor level of key areas of the site was an alternative (pp. 223–4). However, levees do not protect against all eventualities. The final Queensland Inquiry reports a case where levees were used to protect a mine that had suffered flooding in 2008. In 2010–11, while the levees were effective at protecting the site from riverine flooding, heavy rainfall over the site itself flooded active mine pits, causing mining to cease (p. 355).

The Victorian Review makes no recommendation about the use of levees, as this was to be addressed in the parallel review on flood mitigation. However, it does describe some instances where levees were used in the recent floods, including their targeted use to protect essential services. At Kerang, for example, a levee was built to protect the control building of the electricity terminal station – which, had it been inundated, would have caused 20 000 people to be without power during the floods (p. 188). The protection of key infrastructure is discussed further in Section 4.3.

The use of levees to protect existing key infrastructure may be an appropriate use of levees. However, if this option is selected, it needs to be planned in advance. During the recent floods, there were cases where *ad hoc* levees in Victoria exacerbated flooding (Victorian Review, p. 65). This can cause catastrophic breaks or impounding of water on farmland.

As well as protecting essential services, levees have an important role to play in protecting rural townships (Queensland Inquiry, p. 115; Victorian Review, pp. 59, 86). Kerang is a township of approximately 3800 people in the Lower Loddon in northern Victoria. The Gannawarra Shire Council, in its submission on the Inquiry into Flood Mitigation Infrastructure in Victoria, notes that had the levees at Kerang failed, the estimated cost of damage would have been $190 million (Gannawarra Shire Council 2011, p. 6). Thus security – both in economic and social terms – provides a strong incentive for the construction of town levees.

There is a distinction made between levees that protect townships and rural levees. In Gannawarra Shire, the planning scheme does not permit levees to protect farmland due to potential impacts on other properties (the larger the area protected by levees, the higher the floods will be outside the levees due to the reduced floodable area). However, it does allow protective levee banks in the immediate surrounds of a dwelling and nearby out-buildings, providing some level of security (Gannawarra Shire Council 2011, p. 15). Strategic use of ring levees is an option in high-risk areas where relocation cannot be achieved.

Adverse impacts of levees. The ENRC Inquiry does not discuss adverse impacts in detail, though problems of private levees being built close to natural levee banks and transferring floods to neighbouring properties are mentioned (Parliament of Victoria 2012, pp. 60–1, 73).

The Victorian Department of Sustainability and Environment (DSE) submission to the inquiry covers adverse effects of levees in much greater detail, particularly with regard to rural levees. Not only do levees increase flood height, they also increase flood velocity and erosive power. The submission stresses the need to assess cumulative loss of flood storage as a consequence of levee construction. Another impact of levees is that they can considerably worsen the effects of more severe floods by trapping floodwater behind them. By impeding the drainage of floodwater, they increase flood duration.

Rural levees badly affect ecosystems, especially if built on a river's edge. River red gum forests rely on periodic flooding, and if this is prevented they suffer dieback, with knock-on effects to species that depend on them. Levees also block the connectivity of rivers with floodplains, adversely impacting plants, animals, groundwater and the nutrient balance of floodplains. These problems are likely to be exacerbated by climate change. Heritage sites have also been affected by levee construction, with 95% of registered Aboriginal places within 1 km of water sources and non-Indigenous heritage also commonly found close to waterways. DSE recommends that new and modified works need to avoid such adverse impacts, and that there be research into cumulative levee impacts, leading to better management of this aspect. Their submission also recommends that rural levees should be no greater than the 1 in 20 year flood, to enable overtopping and flood water storage during major floods (State Government Victoria 2012, pp. 21, 24–6, 30).

One adverse impact that levees can have, which does not appear to be covered by any of the inquiries, is the encouragement of additional development behind them. This can appreciably increase the consequences (and therefore the risks) of flooding should a levee fail. Atkins and Vince (2009) provide an example of levees tempting increased development in Launceston, Tasmania. In this instance, development controls and threats by state and federal governments to withdraw funding managed to prevent additional development from proceeding.

Levee safety issues. The Brisbane Review is cautious about advocating levees as a flood solution, and points to a number of problems that can result from using levees, such as safety if levees are breached, reduction in flood plain (resulting in bigger floods) and formation of a barrier to natural drainage.

The Queensland Inquiry reports provide little information about the performance of levees during the floods in Queensland. In Victoria, a total of 114 levees were breached during the floods, 90 of these in the Loddon Valley (Victorian Review, pp. 59, 226). However, no formal town levees failed. This category of levee is regulated and maintenance responsibilities are generally clear (State Government Victoria 2012, p. 21).

Reviews report other safety issues relating to levees. Levees can impede flood intelligence and the ability to predict flood behaviour, such as movement and depth (Victorian Review, p. 59). If levees overtop, they can cause considerably greater damage due to the high energy contained in the water, compounded by the complacency of those living behind them (Queensland Inquiry final report, p. 168).

The interim Queensland Inquiry report relates one instance where levees adversely affected preparedness for flood. At Goondiwindi, neither the mayor nor the chair of the local disaster management group had considered it necessary to develop an evacuation

plan based on water level height triggers, 'because they did not think the flood would breach Goondiwindi's levee banks' (p. 189). This highlights a problem that has been noted by other authors: levees can create a 'flood-proof mindset', that can increase the potential for losses (Smith 1998; Atkins & Vince 2009; Thomas et al. 2011).

Levees and future flooding. In terms of a solution for climate change flooding, a flood-proof mindset is dangerous. Flood levees built on the basis of an understanding of historic flood data may not be sufficient to protect lives and property and assets if flooding increases in magnitude. At Kerang, the levees were built to a 1 in 100 year event flood level, yet the flood in January 2011 exceeded this, resulting in evacuation. While temporary works managed to save Kerang on this occasion, Gannawarra Shire's report notes that 'the 1 per cent flood event can reasonably be expected to be exceeded in the future' (p. 13).

For levees to be a reliable form of defence for key assets and population centres, 'design' floods need to incorporate possible climate change scenarios to ensure that levees are designed to withstand floods of greater magnitude. This also raises the question of how to plan for uncertainty, which is an issue that will be examined later in this report.

CBD Flood levees, Wagga Wagga *Photo:* Eric Wenger

Backflow prevention

Mechanisms to prevent backflow include one-way valves, floodgates and river barriers. Backflow prevention devices are discussed in the Brisbane Review and Queensland Inquiry as an option to address stormwater or sewage backing up through the piped system. Both reports are cautious about recommending the use of these devices, noting issues with expense, maintenance and effectiveness. They both recommend risk assessment as a prerequisite to installing backflow prevention devices. Use of backflow prevention is only strongly supported in specific cases – such as to prevent sewage rising from drains inside low-lying houses during floods (Brisbane Review, pp. 61–2, 67; final Queensland Inquiry, pp. 227–8, 234–5, 239).

Need for maintenance is commonly raised as an issue in relation to flood infrastructure in general. The Brisbane Review notes the importance of maintenance work of the stormwater network, and it has an annual maintenance and repair schedule (pp. 63–4). The interim Queensland Inquiry report notes that drainage channels and flood gates were cleared by a number of Councils as part of their preparation in response to BoM forecasts prior to the 2010–11 floods (p. 115). However, this did not happen everywhere. A channel constructed around the Rocklea Markets following the 1974 flood had become layered with debris, rendering it ineffective as a mitigation channel (p. 224). This suggests there needs to be a closer correlation between forecasts, and preparation measures in emergency management plans – particularly with regard to essential

services such as the markets. If flood mitigation infrastructure is constructed, provisions need to be put in place for its maintenance.

Detention basins

The final Queensland Inquiry report briefly examines the role of detention basins for managing stormwater (pp. 234, 597–9). Detention basins are 'dry dams' constructed to capture floodwaters. An additional benefit is that they can be designed to improve water quality by allowing time for sediment to settle before water is released. The Inquiry notes that detention basins are of particular importance in managing large, sudden inundations (p. 234). As flash flooding is expected to increase with climate change, this is a measure that may warrant further investigation.

The Inquiry reports a common land development practice used in floodplains, whereby low-lying land is built up by using fill dug from hills or trucked in from other development. Rather than protecting natural detention basins, it seems that they are more often filled in and built on. This practice is often implicated in the flooding of adjacent properties (pp. 162–7).

The construction of artificial detention basins can be costly in terms of the amount of land they require, continuing maintenance costs and the opportunity cost of land not being available for other purposes. This limits their use in densely built areas, such as CBDs (Queensland Inquiry, p. 234). The Inquiry report does not discuss the dual purposes such land can serve, such as recreation and wildlife habitat (NSW Government 2004).

A series of detention basins in Toowoomba is studied separately in the Inquiry report, with concerns that, taken as a system, they could be classified as referable dams (i.e. dam failure would endanger the lives of two or more people).

The Brisbane Review refers to the proposed construction of flood mitigation dams upstream from Ipswich as being beneficial for mitigation of flooding in Brisbane (p. 61). It is not clear from the report whether these would be detention basins or dams with combined storage and mitigation functions, similar to Wivenhoe Dam.

4.1.6 Land management

Modifying land management so that it is better able to withstand flooding is not a measure directly discussed by either the Victorian Review or the Queensland Inquiry. However, it is alluded to in a few instances that will be examined here. The ENRC Inquiry, on the other hand, devotes an entire chapter to the ownership, management and maintenance approaches of waterways (pp. 99–144).

Farming systems

The Victorian Review examines various forms of recovery grants provided by different levels of government, among them the Victorian Government's voluntary buyback scheme in the Lower Loddon (p. 196). One of the primary aims of the Lower Lodden Irrigators Recovery Package is to convert the land from irrigated uses (primarily broadacre and dairy) to more appropriate, flood-resistant dryland farming systems. While the package assists the financial recovery of landholders, it can also be seen as preventative in that it will avoid future losses.

Should farmers wish to participate, they are offered two options. They can either sell their irrigated land at pre-flood values (after which it will be resold as a dryland farm), or they can remain on their land and receive compensation as a percentage of the pre-flood land value to place a covenant on the title of their land to restrict its use to dryland practices (Department of Sustainability and Environment 2011a). $12.3 million was allocated to this package for the conversion of an irrigated area of 2750 ha. Flood-

affected dwellings with minimal residual value are to be demolished, some relocated and some, where possible, protected individually by ring levees. The program was successful in being able to purchase all but two properties in the area identified as having the greatest risk (McBeath, pers. com.).

Erosion and riverbank slumping and vegetation management

One consequence of the floods in Queensland was significant loss of land due to riverbank slumping. Landowners reported land losses of up to 30 hectares (final Queensland Inquiry p. 574-578). DERM and the Queensland Inquiry commissioned some studies into whether dam management might have caused the slumping. The conclusion reached was that dams did not exacerbate the riverbank damage, as they reduced the peak and allowed for more gradual recession of floodwaters, allowing banks more time to drain. Moreover, there was a lack of correlation between water levels of the dam and one of the creeks studied, where significant slumping occurred. The most likely way dam management could have affected the slumping was by increasing the duration of inundation, which may have increased saturation of the banks. As a result, the Queensland Inquiry makes a recommendation to extend the length of time dam managers are allowed to draw down the lake to slow the recession of floodwaters, gently challenging the current priority of convenience for bridge users versus long-term damage to land.

Rather than dam management, the Queensland Inquiry studies point to landholder activity in the form of land clearance as a significant factor in riverbank slumping: 'the effect of floodwater on riverbanks may … be mitigated considerably by vegetation growing on and around riverbanks' (p. 576). This finding is confined to a short paragraph in the text of the report, and no formal recommendation is made regarding the potential for revegetation of riverbanks by landholders to combat this problem.

Increased land erosion is a recognised consequence of climate change flooding due to increasing rainfall intensity and magnitude (Pittock 2003; Bates et al. 2008). Moreover, this is likely to result in significant movement of sediment, which can change flood behaviour, reducing flood predictability (e.g. where flooding will occur and its magnitude). Increased sediment loads due to climate change are expected to reduce water quality (due to turbidity and pollutants), increase sedimentation of lakes and adversely affect reefs (Pittock 2003). Sedimentation also has the potential to impact dam reservoirs, reducing their storage capacity during times of more severe climate change-induced droughts.

Stabilisation of riverbanks by revegetation, suggested in the text of the Queensland Inquiry report, may be a key strategy for mitigating against climate change flood-induced erosion and sedimentation. If native species are used, revegetation also has well-recognised ecological and water quality benefits.

Beyond stabilisation of riverbanks, revegetation can be useful to reduce run-off and erosion of farmland beyond the riverbanks. Floods can cause loss of topsoil and organic matter in the soil, reducing soil depth, nutrients and water-holding capacity, and degrading soil structure (Pittock 2003). According to Pittock, risk of erosion increases greatly once ground cover falls below 70%, a situation more likely to occur under climate change conditions due to drought and wildfire (pp. 110–11). He recommends incorporation of plantations and farm forestry into farming systems as one method of combating increasing erosion and sediment loads (p. 94).

Vegetation management is thoroughly covered in the ENRC Inquiry, this being part of its terms of reference. A significant issue identified in this respect was the community perception that vegetation and debris in waterways has an adverse effect on flooding

(pp. 114–18). These views are not limited to Victorian communities, but were also reported by this project's interviewee participants from Queensland. This misperception encourages people to clear channels, which actually worsens flooding on a landscape scale: 'following the 2010–11 floods, some councils had vegetation removed and channels widened to reduce community concern' (p. 117).

The Inquiry report goes to some trouble to explain hydrological concepts in understandable terms in order to help to dispel these myths. The effect of vegetation on a catchment scale is to reduce water velocity, reduce flood peaks and reduce peak discharge. It also prolongs the duration of flood events by slowing discharge. In one study, flood duration was extended from two to three days, to four to five days (pp. 121–9). On a local level, vegetation can increase flood heights, but localised effects are generally insignificant. By way of example, the ENRC reports some modelling that was done of the 2010 and 2011 floods in Creswick. The model demonstrated that 'clearing vegetation and blockages from the channel would have reduced the height of the floodwaters by about 15 centimetres, but this would not have altered the number of houses flooded' (p. 113). Transport infrastructure, bridges, large dams and flood levees were viewed as being much more significant in affecting flooding than vegetation (pp. 112–13, 128). Indeed, research reported under the levees section of this report indicates that floodplain levees can significantly increase the erosive power, water depth and duration of flooding. If they are overtopped, they can trap water behind them and prolong flooding for months rather than days.

The values of revegetating banks were also explored by the ENRC Inquiry, with revegetated reaches experiencing 80–95% less erosion than cleared reaches and little change to channels. Ideally, sites needed to be continuously revegetated to a width of at least 10–30 m each side of the creek (p. 123). Legal provisions for waterways in Victoria no doubt play a large part in enabling revegetation and management activities to occur. Riparian land, often 20 m in width, is included in a reservation system established in 1881. Known as Crown land frontages, these strips total about 25 000 km (p. 103).

Some of the recommendations in Chapter 5 facilitate the removal of vegetation and debris under certain circumstances. However, the report's recommendations with regard to vegetation management generally target the development of policy and processes rather than positioning for or against vegetation removal. Recommendations provide for codes of practice to be developed, and for strategic implementation of vegetation and debris management, requiring policy guidelines, flood-risk criteria and identification of specific reaches that will need ongoing management. Flood investigations currently are being carried out for a number of towns along similar lines to the investigations at Creswick (p. 114). This hopefully will ensure a sound basis for identifying reaches that need to be managed.

While the ENRC Inquiry makes no recommendation regarding education, it does relay a recommendation by the Victorian Department of Sustainability and Environment:

> local governments and CMAs should educate their communities about the real magnitude of flood protection provided by clearing debris and vegetation from streams and stream banks … [to] ensure that communities do not place undue emphasis on this aspect of flood management, at the expense of other measures which could provide better protection, such as land use planning (ENRC Inquiry, p. 119).

This same need is echoed in the interview findings of this report.

Case Study
Co-benefits of wetlands in Australia, Leeton

Leeton Shire is home to Fivebough and Tuckerbil Swamps, a listed Ramsar wetland site since 2002. A total of 159 species of bird have been identified in its diverse wetland habitats, including 24 that are listed under international migratory bird agreements.

In the 1990s, a proposal was considered to develop the wetland into a recreational lake, which would have severely harmed its habitat values. This proposal was abandoned and instead, plans were put in place to manage the area as a wetland. This has provided significant benefits to the town for floodwater storage. In March 2012, 11 inches (275 mm) of rain fell in the area over two days, overwhelming the town drainage system. This floodwater drained naturally away from the town of Leeton and into, among other areas, the Fivebough wetland, which would not have been possible if the wetland had been destroyed or developed.

The shire has made the most of the tourism potential of the site by participating in the organisation of an annual Birdfair. It is estimated that in most years the Birdfair draws 300–400 people to the area. The wetlands also attract tourists throughout the year although the number of bird watchers is difficult to quantify. The type of tourists attracted to the wetlands is well-educated and affluent.

Studies are being undertaken over the next 12 months to quantify the economic value to the town. As an estimate, the 'front door' value is $50,000 of direct income but there are also numerous multiplier effects, estimated to rise to many times that amount. Further investment in the site, such as raised walkways, could broaden its appeal and increase the site's tourism potential. However, the benefits of the wetlands are not just economic. Leeton Shire's Manager of Economic Development, Tourism and Events suggests that the wetland's social values could exceed its economic value.

A recent change to the leaving age of students at high school requires children to remain in the education system until the age of 17 unless they have employment. Retaining these disenfranchised students in schools when they would rather be doing hands-on work causes frustration for students and disruption for teachers. To solve this problem, Leeton Council, schools, the local land council and TAFE have collaborated with site administrators to develop some hands-on courses for these students at Fivebough wetlands. Students create signage about species and points of interest, build brick gateways and carry out other valuable tasks for the park, including maintenance.

Through the course they learn about the wetlands as well as skills such as brickwork, metalwork and woodwork. Leeton Shire believes the community service value is enormous, because as it is the students who are building the infrastructure, they have pride in the work, resulting in little or no vandalism and thus savings from reduced maintenance. As the project has such broad community participation, it has already attracted interest across the state as a functioning partnership and hopefully will attract additional funding for greater works, such as a raised walkway.

Sources: Schultz (2004); Peter Kennedy, Manager of Economic Development, Tourism and Events, Leeton Shire Council.

4.1.7 Rebuilding elsewhere

Relocation of flood-prone communities is an effective option for flood prevention in areas that are flooded frequently. This strategy has been used numerous times in Australia's history, and the towns of Bega, Nowra, Gundagai and Smithfield (now a suburb of Cairns) all owe their present locations to catastrophic flooding. However, relocation is often resisted despite opportunities to move and repeated flooding (Coates 2011, pp. 3–4). In the Brisbane Review and the Victorian Review, relocation is discussed as an option via voluntary buyback schemes and compensation for rezoning or establishing covenants on land.

The Voluntary House Purchase Scheme in Brisbane, worth $5 million, aims to purchase houses in regularly flooded areas (two-year average recurrence interval) so residents can relocate to less flood-prone areas. While costly, this solution is able to address the inadequate land use planning decisions made in the past. The Brisbane Review recommends additional resources for this scheme so it can also cover areas of less frequent flooding. The uptake of the scheme by Brisbane residents has been low, though the reasons for this are not examined in the review (Brisbane Review, pp. 58–9).

As discussed above in Section 4.1.6, the Victorian government has offered a buyback scheme of $12 million to irrigators in the Lower Loddon. This necessitates identifying the boundaries of the floodplain. The Victorian Review makes no specific recommendation in relation to the scheme (p. 196).

While relocation of Brisbane's CBD may not be feasible, it can sometimes be an option to relocate smaller settlements. In Grantham, many lives were lost and property damaged beyond repair. As a consequence, relocation of the community was seen as the best option for recovery and to prevent recurrence. The Lockyer Valley Land Swap Project, costing close to $3 million, aims to move residents of Grantham on to higher ground (Queensland Government 2012a). Residents are responsible for the cost of building on the new blocks. Approximately 70 families had participated as at the end of December 2011. Significant planning has gone into the Grantham relocation, organised through the Queensland Reconstruction Authority. The flood zone land that was swapped now belongs to the Lockyer Valley Regional Council. It is most likely to be used for parklands, community market gardens and farming (Queensland Government 2011c).

The final Queensland Inquiry report notes that the cost of the Grantham land swap is to be offset by the sale of land ballots at a later stage in the process. This will allow other lots to be developed and sold to provide revenue for the council. Factors that could influence the suitability of land swap as a measure include the availability of nearby undeveloped and unconstrained land and council's financial resources (pp. 272–7).

4.2 Preparation and planning

4.2.1 Community resilience

Community resilience is currently at the forefront of recent emergency management literature and at conferences in Australia – possibly as a result of its inclusion in the 2011 National Disaster Resilience Strategy. In the recent flood reviews, a chapter is devoted to increasing community resilience in the Victorian Review, and relevant issues are also discussed in other sections. The Brisbane Review and the Queensland Inquiry do not address community resilience in the same level of detail, but recommendations contribute to this goal.

The recent flood reviews have shown clearly that response agencies are not equipped to deal with flooding on the scale of the 2010–11 floods. Every review revealed severe inadequacies in terms of numbers of response personnel, their training and equipment

(design and quantity). Large-scale floods are expected to increase in likelihood with climate change, so inadequacy of response resources for such events is a key issue.

While deliberately incorporating redundancy in emergency management processes may be an option in terms of developing 'failsafe' mechanisms, it is not feasible to expect that governments should maintain large standing armies of flood responders when severe and widespread flooding is unpredictable from year to year (Handmer & Dovers 2007, pp. 26, 95). This view reinforced by the Victorian Review, which quotes the Queensland 'Harden Up' campaign:

> Weather events are getting more severe and when a major weather event hits, you cannot rely on government and volunteer organisations to help. You need to harden up by preparation, awareness and helping others. (Victorian Review, p. 220)

Communities and individuals cannot expect that when a large flood happens, ample staff will immediately be on hand to rescue them. The larger the flood, the more likely it is that individuals will have to cope alone. As a consequence, 'community resilience' has become a key policy, and individuals are expected to share responsibility for emergency management (COAG 2011). If climate change is expected to increase the risk of large-scale complex floods, increasing community resilience is relevant and warrants further examination.

Resilience can be defined as the ability to *withstand an event* and the ease with which one can *bounce back* from it. Thus resilience could be interpreted as 'response' and 'recovery'. How well you are able to respond and recover will depend very much on your ability to prevent, mitigate and prepare prior to the event. In many respects, resilience is therefore a reinvention of the well-established PPRR approach to emergency management. In a community context, this can encompass many different aspects, such as recognising and avoiding risk prior to an event, understanding local emergency management arrangements, preparing household emergency management plans (covering appropriate response to warnings to ensure protection of lives and property), access to information during an emergency and insurance coverage. The Victorian Review also discusses some characteristics of resilient communities, such as strong community networks, partnerships to help incorporate local knowledge, business continuity planning and volunteering.

While community resilience covers the whole spectrum of prevention, preparation, response and recovery, it is addressed in this section on preparation because implementation of a community resilience strategy can be viewed as part of the preparation that needs to be undertaken by government.

Awareness of flood risk is seen as a key factor in increasing community resilience. If local governments and individuals are aware of the flood risk of an area they wish to develop or purchase, this will assist them to assess their own risks. This issue is covered in all flood reviews (Victorian Review, p. 73; Brisbane Review, p. 36; Queensland Inquiry final report, pp. 60, 69–71). There are some problems associated with this. Impacts on land values and insurance cost are discussed in the Victorian Review (p. 196). The Queensland Inquiry notes that possible downsides to public availability of flood risk information include intellectual property, impacts on land values, insurance prices and liability for incorrect information. It suggests these issues could be addressed via a central repository of flood study data, with contractual arrangements for the deposit of and access to the data (p. 59). Despite these downsides, reviews are unanimous in supporting publicly available flood risk information. A further point to note is that Geoscience Australia has a National Flood Risk Information Project, so freely available information on flood risk seems to be the direction in which Australia is headed.

The final Queensland Inquiry examines various mechanisms to improve awareness of flood risks, such as disclosure requirements for contracts for sale of land (seller obligation), rates notices, incorporation of flood search into contracts of sale (purchaser obligation) and availability of development approval information online about conditions binding the use of land. The latter two were seen to be most promising approaches (pp. 69–71). In addition, all reviews recommended that information be included that would allow easy interpretation by the public. Maps are recommended as an easy way to portray information (though the Queensland Inquiry notes that in Queensland this is not a legal requirement and not all councils have the resources to provide flood maps, which are expensive to prepare) (p. 62).

The Brisbane Review commends the implementation of FloodWise and FloodMap, and suggests their further development to enable the public to assess individual property flood risks (Brisbane Review, p. 36). Potentially, this could allow people to access timely, property-specific information on flooding during flood events, as well as provide a tool empowering individuals to assess flood risk before purchasing property. Such information would reduce vulnerability and ensure sensible development decisions are made and are widely understood by the public.

While public awareness of flood risk is important to support community resilience, it has its limitations. It is significant that the Queensland Commission found that 'purchasers of property, in making the decision to purchase, did not turn their minds to the property's vulnerability to flood' (p. 70). There are also socio-economic implications in that, even if risks are widely known, poorer people may not be able to afford the higher purchase price of living in areas with low flood risk (see discussion of satellite legislation, above). Neither would risk awareness benefit vulnerable people accommodated in aged care facilities, hospitals and child-care facilities, which are also often sited without adequate consideration of flood risk (Queensland Inquiry final report, p. 150). Thus risk awareness is no substitute for good planning and development controls.

Local government has a significant role to play in assisting the community to prepare for floods. The interim Queensland Inquiry report note examples where councils and the media helped residents prepare well, including information about risk of flooding, the meaning and significance of warnings, contact numbers for emergency services, how to plan for disasters and evacuation planning. Ways in which councils can support local businesses to plan for flooding are provided in the final Queensland Inquiry report (pp. 394–6).

Problems are often encountered in ensuring that people prepare for floods. For example, the Brisbane Review discussed the difficulties in convincing people of the need to prepare for flooding after a period of prolonged drought (p. 33), as well as local councils failing to see the need for developing flood plans due to the drought (Victorian Review, p. 183).

The efficacy of the community resilience approach has been questioned, with suggestions that is not evidence based (Goode et al. 2011, p. 20). However, simultaneous research undertaken by the Victorian Flood Review found that the VIC SES FloodSafe program did improve community awareness and response (p. 84). Thus its recommendations regarding community education programs hold promise for climate change adaptation.

Flood marker under Hampden Bridge, Wagga Wagga
Photo: Eric Wenger

Other recommendations to improve community resilience issues relate to improving flood warnings, ensuring appropriate community response to warnings, the protection of essential services (e.g. to enable information dissemination to the community during events) and insurance. These are addressed in relevant response and recovery sections later in this report.

4.2.2 Emergency management planning

While emergency management does not address the underlying causes of flood damage, it manages the residual risk that remains after prevention and mitigation (Queensland Inquiry final report, p. 68; Handmer & Dovers 2007, p. 99). With climate change, more people are likely to be exposed to flooding as a result of increased sea level changes, more prolonged or intense precipitation events, or flooding in different locations where houses are not built to withstand flooding. The number of Australians exposed to flood risk is likely to double with an increase in global mean temperature of 1–2ºC (Gissing et al. 2010). This will be compounded by demographic factors, such as a high proportion of vulnerable people (elderly and low income) living in coastal areas, and population pressures that are likely to push development into unfavourable areas (Australian Government 2009).

With increasing exposure to hazards, emergency management will become increasingly important, particularly if the proactive implementation of preventative measures does not improve.

The planning for emergency management in Queensland and Victoria reveals some common issues. In both states, emergency management planning occurs at different levels (local/municipal, region/district, state). These cover general emergency response provisions and can include sub-plans (e.g. covering specific hazard types such as flood or to guide evacuation, resupply). There are also emergency planning processes within different portfolio agencies and response agencies. In Victoria, incident action plans guide the response for a specific event. Recovery is coordinated via separate recovery plans. The requirement to develop emergency management plans is generally legislated, though not all types of plans are included (for example, there is no legal requirement for regional emergency management plans or flood sub-plans – see Victorian Review, p. 183).

While emergency planning occurs at all levels of government, there were some particular challenges for *local governments*. Local councils are legally required to resource and prepare Municipal Emergency Management Plans in Victoria, but have varying capacity to do so. Local governments differ greatly in terms of demographics, area of land (and amount of infrastructure, such as roads) for which they are responsible, geographic vulnerability to disaster, experience and resources available (Victorian Review, pp. 200–1; Queensland Inquiry interim report, p. 160). In Queensland, local disaster-management groups are seen as having a pivotal role in planning and response activities, and this is viewed as appropriate, with the proviso that they are given the necessary resources and guidance (Queensland Inquiry interim report, p. 114). In both states, council amalgamations have taken place, which is not always reflected in local-level disaster-management planning (Queensland Inquiry interim report, p. 118; Victorian Review, p. 201). In Victoria, changes in procurement processes have meant that councils no longer have the resources available to them that they did when emergency management legislation originally was passed in 1986, suggesting that a revision of their role in emergency planning is needed (for resourcing issues, see Section 4.3). The role of municipal bodies needs to be complementary to that of Incident Control Centres, which are also responsible for logistic response (pp. 201–2).

Inconsistent *boundaries* were a particular issue for planning emergency response, as natural catchment boundaries do not coincide with the various administrative boundaries involved. In Victoria, the SES State Flood Response Plan states that regional flood plans need to be based on the regional boundaries used by the SES and Department of Human Services, as well as reflecting natural catchment boundaries. However, neither these nor municipal boundaries coincide with catchment boundaries. The Victorian Review recommends that emergency planning should be based on geographic risk rather than administrative boundary (pp. 182, 204–5). In Queensland, coordination of response was complicated by lack of consistency between administrative boundaries, including local government boundaries, disaster district boundaries (administrative), police district boundaries, emergency services boundaries (e.g. fire and rescue service) and state agency boundaries. Using the natural geographic boundaries of the disaster was seen as having little use in large-scale disasters like the 2010–11 floods, which affected most of the state. However, improving the alignment of administrative boundaries was seen as a long-term objective (Queensland Inquiry interim report, pp. 198–202).

Both states had significant issues with the *quality of plans*. The content of Victorian SES regional flood plans generally directly copied information contained in state plans, with little correlation between the plan and the actual response. State and regional flood emergency plans were also considerably out of date, breaching requirements (pp. 133, 182). Sometimes flood sub-plans of municipal emergency management plans were only draft or incomplete (p. 133). Victorian regional emergency management plans are described as ‘aspirational at best’, with no capacity assessment to provide assurance that, in a widespread or protracted emergency, agencies are able to fulfil the roles assigned to them (p. 183).

In Victoria, incident action plans are developed to ensure control is established (defined as overall direction of the response and tasking other agencies – see p. 114). They document structures, who is in charge, their location, what needs to be done by whom, how and in what priority (p. 130). The quality of local-level incident action plans varied, with some containing insufficient detail and no clear management structure. The review suggests that to address this, there needs to be a standardised approach to development of incident action plans of all levels (state/region/municipal) and across agencies, including standards and best practices for planning processes, pro formas and templates (pp. 124, 133–5).

In Queensland, a similar issue of variable quality was identified with local disaster management plans. In that state, the production of disaster management plans is already subject to some standardisation through Emergency Management Queensland guidelines. However the guidelines do not provide sufficient detail to produce quality plans. Some plans did not identify risks such as isolation of communities. Some contain insufficient contingency planning for back-up sources of power, facilities or means of communication (see also contingency issues in Brisbane Review pp. 34–8). The guidelines are currently under revision (Queensland Inquiry interim report, pp. 118, 161). Both states identify a lack of capability and capacity assessment in planning, and recommend documented assessment processes or standards (Victorian Review, pp. 124, 135, 183; Queensland Inquiry final report, p. 406).

Another issue was that response *plans sometimes did not exist*. This appears to have been more of a problem in Victoria than Queensland. If a municipality is subject to a specific hazard, planning for it is an expected (though not a legislated) requirement. However, many municipal plans did not contain flood sub-plans, despite being located largely on floodplains. These flood sub-plans can be an important source of information for incident action plans (Victorian Review, pp. 133, 183–4). There was no state level incident action plan, despite this being a legal requirement. There was also a lack of regional-level incident action plans. Sometimes where plans existed, they were not known about or were unavailable. The lack of incident action plans caused responses in some places to be reactive rather than planned, with ad hoc warnings, evacuations and rescues (pp. 134–5).

A solution in terms of both the quality and creation of plans includes improved *review and audit* (Victorian Review, pp. 116, 149, 183–4, 199; Queensland Inquiry interim report, pp. 114, 119; Queensland Inquiry final report, pp. 400–1). Audit was needed of both regional and local plans, with independence of the auditing agency also being an issue (Victorian Review, pp. 184, 199). The Queensland Inquiry reports that an effective review system has been created since the publication of its interim report. Coordinated by the state-level Emergency Management Queensland (EMQ), district disaster management coordinators review the plans from their areas, using a standardised approach to review using a workbook and training provided by EMQ. EMQ assesses review results and also reviews a sample of plans as further quality assurance (p. 400).

4.3 Emergency response

4.3.1 Forecasts, warnings and community response

> up to 80% of potential flood damage within buildings in urban areas could be avoided if people were better warned, knew what to do … and were persuaded to act accordingly. (Comrie 2011, p. 31)

Forecasts and warnings are of great importance in reducing the impacts of floods, and many of the reviews' recommendations look at fine-tuning existing systems. This clearly has relevance for climate change, as it has the potential to reduce damage and fatalities from increased flooding frequency and magnitude.

However, the merit of warning systems in relation to prevention measures needs to be kept in perspective. The Victorian Review notes that 'the necessity for flood warning systems is reduced in areas where floodplain development has occurred consistent with the level of flood risk, for example building construction above flood levels' (p. 31).

Coverage of warning networks

The Victorian Review discusses the elements of a flood warning network in its first chapter (p. 33). In 2010–11, areas were flooded that had not previously been thought of as flood prone. Water flowed in unexpected directions, and sometimes did not follow

normal watercourses (p. 34). This has relevance for climate change, in that the location of floods may change.

The review reports that the *ad hoc* approach to funding and arrangements for ongoing costs has meant that the coverage of flood warning networks is very fragmented, leading to significant data gaps (pp. 41, 48). Disturbingly, there appears to be no correlation between flood risk and the coverage of the flood warning network (p. 43).

The Victorian Review recommends that flood warning systems be developed for each basin, to ensure adequate coverage of warning systems, including places not previously known to be flood prone. This will be particularly useful for areas that can expect increased precipitation intensity due to climate change.

Data collection

Adequate data collection and interpretation of flood behaviour via flood information systems are prerequisites for accurate and timely flood warnings. With climate change, Eastern Australia can expect more flash flooding due to more intense precipitation events, as well as an increase in 'unprecedented' events, so any improvements that can be made to data collection and warning systems will be of great importance in coping with this.

The reviews all reveal issues with the type and distribution of gauges for measuring stream flow and precipitation. Strategically placed gauges can improve both the timeliness and accuracy of forecasts and warnings. For example, at Emerald, the interim Queensland Inquiry suggests that a well-placed gauge might provide the council with 12–24 hours of additional warning time (p. 134). The Inquiry also discusses the lack of gauges in the upper catchment above the Wivenhoe Dam, which contributed to the disregard of rain forecasts when determining which dam strategy to operate (pp. 62–3).

The types of gauge used are also discussed, with ALERT gauges being seen as the most useful for flood warnings, including flash flooding. These gauges transmit data continuously in real time rather than at periodic intervals, and they can also automatically send warnings via SMS or email to council staff when triggers are reached – such as river height (p. 134). The Victorian Review similarly recommends the use of automated gauges that transmit data in real time (p. 49).

The Victorian Review notes that a significant proportion of stream gauges were damaged during the Victorian floods, raising issues relating to equipment resilience and the need for contingency measures to obtain data during floods (pp. 50–2).

Resourcing

Resourcing issues are a big impediment to improved coverage of data collection. The interim Queensland Inquiry report recommends state government assistance to install gauges, particularly in areas susceptible to flash flooding. It also notes assistance is available under the Commonwealth Natural Disaster Resilience Program. However, once gauges are installed, councils incur an ongoing maintenance liability (p. 134). While the Queensland Inquiry recognises ongoing maintenance as an issue, this is not addressed in the recommendations.

In Victoria, monitoring is overseen by the state government, which arranges surface water monitoring contracts on a cost-sharing basis, reducing overall cost. It notes more than once the inadequacy of current arrangements, whereby the cost of maintaining gauges is borne by local government, resulting in data gaps (pp. 42, 50, 52). While no specific recommendation is made regarding maintenance of gauges, the review does recommend the clarification of roles, responsibilities and cost-sharing arrangements for

flood warning systems (p. 44). In some cases, dam owners and operators could be made responsible for data collection (Victorian Review, p. 69).

Planning for the unprecedented

The word 'unprecedented' is used repeatedly in the reviews to describe flooding incidents in some areas (e.g. Victorian Review, pp. 123, 157, 194). Yet 'unprecedented' is a defining characteristic of climate change flooding, both in terms of location and magnitude.[5]

A description of one such event is given in the interim Queensland Inquiry report: 'the Helidon gauge spike' (p. 150). Information from stream gauges to monitor river height at Helidon is fed remotely into the BoM information system. The Queensland Inquiry reports that on 10 January 2011, the BoM computer automatically marked most of the gauge readings as incorrect. Moreover, BoM staff believed that the readings were characteristic of a faulty station. The gauges did indeed fail when the water rose so high that they were inundated. However, the assumption by BoM staff that the earlier readings were faulty proved incorrect. This displays failures on many levels, including the BoM computers interpreting data as wrong, the positioning of the gauges being insufficient to cope with the depth of the flood, the interpretation of data by BoM personnel and the lack of corroborating sources of information.

The Queensland Inquiry made no recommendation regarding the majority of these failures, excusing them on the basis of the unprecedented nature of the event (an attitude taken by all the reviews to such events). However, it did recommend use of amateur weather watch groups as an additional source of local information that could be used to confirm unexpected results on the ground, and measures to improve communication between BoM and these groups (p. 152). The report notes that 'automated systems are extremely useful, but their existence should not lead to disregard of the value of human observation and local knowledge' (p. 151).

If operating in a changing climate change, we need to become more adept at preparation and planning for the unprecedented. This could include better data gathering, flood intelligence systems, and warnings, as well as attitudinal change. Agency staff and the public need to be aware that the 'unprecedented' is now more likely to happen. Rather than responding with disbelief to unexpected data, there need to be 'failsafe' verification systems.

Warning communication systems

The Victorian Review endorses the Total Flood Warning System as the best-management practice that should be adopted for providing warnings (pp. 31–2)

The governance of the flood warning network is discussed in the Victorian Review, which notes that there is a need for clarification of the respective roles and responsibilities of BoM, state government agencies and local government. Consideration of expertise and resources both need to be factored into this, and the report suggests that some responsibilities fall inappropriately on local government. The lack of clarity in the current framework has led to a lack of accountability and inadequate service delivery (pp. 39–40). The interim Queensland Inquiry provides further evidence to support this view. While some councils were directly contacted by BoM, many badly affected localities – such as Toowoomba – were not (Queensland Inquiry interim report, p. 144). Publicly available information provided by BoM was generalised and related to regions rather than identifying specific localities. This meant that people needed to be aware

[5] Generally, 'unprecedented' means the 'worst on record'. As Australia has very short record of collecting flow data, floods within natural variability are also likely to exceed those previously recorded.

which region they were in. The Lockyer Valley was included by BoM in the 'Southeast Coast district', despite being some distance from the coast (p. 143). The interim Queensland Inquiry report makes several recommendations relating to improving the communication of warnings by BoM to local councils and for public release. The Victorian Review supports the Queensland Inquiry findings that generalised warnings are not sufficient (p. 78). Clarification of the service provided by BoM is being remedied to some extent through the development of service level agreements between BoM and the state and Commonwealth governments (p. 43).

While local governments (and VICSES in Victoria) are primarily responsible for issuing flood warnings to people within their municipalities, dam operators are responsible for warning those downstream of dam outflows, in view of the fact that water levels can threaten before councils have time to issue warnings. They are also responsible for communicating information about outflows more widely to BoM, state government, local councils and emergency response personnel. Recommendations of both the Queensland and Victorian reviews were aimed at improving communications processes – for example, through employing dedicated communications staff, streamlining situation reports via a single pro forma document for distribution to all interested parties, use of the web to communicate with the public and media, developing communications protocols and communications procedures in their emergency action plans and making operating manuals and emergency management plans publicly available (Queensland Inquiry interim report, pp. 67–70; 137–40; see also Victorian Review, pp. 55, 67–9).

Communication to the community

Communications systems ensure that individuals can access information on emergency arrangements (e.g. evacuation centres), warnings and situation updates; they also provide information and request assistance. If communities are expected to be more self-sufficient in coping with large-scale emergencies, they need accurate and timely information.

Problems were experienced with the *timeliness and content* of flood warnings. Many people received warnings too late, and the content of the messaging was not always adequate for them to understand the scale of the flooding or to produce the right response (e.g. Victorian Review, p. 80). The reasons for these problems were manifold. In some cases, communications systems were overloaded (Queensland Inquiry interim report, p. 130). Where flash flooding occurred (e.g. at Grantham), there were issues with data collection, and the speed with which waters rose gave insufficient time to provide warnings. Sometimes information included in warnings was not easily interpreted by the community. For example, warnings referenced gauge heights (you need to know where the gauge is in relation to your property and what the implications of the gauge's height are for your property), and use of road names that were not in use locally. This is far from an exhaustive list of the issues with content.

Various solutions are proposed, such as predetermined templates to reduce drafting time, and to ensure appropriate language and information are included. This would benefit both timeliness and accuracy of warnings. Improved communications processes and greater clarity about the area covered by warnings were important issues to ensure those at risk were aware that the warning applied to their area (see above). One particularly useful tool was described in the Brisbane Review: the web-based tools FloodWise and FloodMap. The review suggests that there is an opportunity to further develop these tools to enable people to access property-specific information to help them predict flood levels and plan for evacuation (p. 37). The interim Queensland Inquiry also discusses the Brisbane flood model 'the Bender', which can integrate numerous factors influencing flooding in Brisbane, including dam releases, river heights and

tributaries. It enabled councils to access and provide property-specific flood information (p. 136).

The Victorian Review notes that there is a conflict between the provision of accurate warnings, as opposed to timely warnings. It suggests that timely warnings be given to provide *lead time*, and that progressive updates can improve accuracy. However, for such an approach to work, it will be important to convey the level of uncertainty in the forecast (p. 72).

The reviews all stressed the importance of a *variety of communication methods* to suit different situations and reach different groups in the community. This includes systems not dependent on electricity supplies. For example, measures appropriate for people on roads include road-closure signs, use of tourist information centres to provide information and radios (Victorian Review, pp. 90–2; Queensland Inquiry, pp. 131–3, 142–3). For flash floods, the interim Queensland Inquiry report suggests that the use of sirens could help to ensure timely warning – providing residents understand the meaning of the siren (p. 132). This could be addressed via community education programs such as FloodSafe (p. 84).

The Brisbane Review discusses a significant breakdown of communications when the web portal it was using became overwhelmed. This affected community access to flood maps and flood information, and also impacted on council's email and data systems. The website was converted to a static website and website operation was moved to be hosted externally to relieve demand on the council's system. SMS alerts were also delayed due to network congestion and reduction in capacity of mobile towers due to power loss (pp. 34–5). Large-scale flooding is expected to increase with climate change, and it is important to ensure that communication systems have the *capacity* to accommodate vastly increased numbers of people accessing communications services for information or to provide reports.

Flash flood warnings. Flash flooding is caused by high-intensity, short-duration rainfall. It is defined in Australia as 'flooding that occurs within six hours of the start of the rain that causes it' (Victorian Review, p. 45); thus warnings need to be prompt. Climate change is likely to increase flash flooding (Nott 2006). However, both the Queensland and Victorian reviews suggest that current arrangements for flash flood warnings are inadequate (Queensland Inquiry interim report, p. 143; Victorian Review, p. 78).

BoM only provides generalised warnings of conditions likely to lead to flash flooding and technical support. Local government is primarily responsible for providing warnings flash flooding, though not all councils were aware of this responsibility (Victorian Review, pp. 39, 45–8). A particular issue with flash floods is the inherent difficulty in predicting them, as they are often the result of intense but extremely localised weather events, which may not be covered by weather gauges (pp. 34–5). Some warning systems were compromised by old hardware or staffing issues (p. 40). Another issue was an emphasis on data and forecasts, and too little attention given to message construction and community education (p. 45).

The Victorian Review indicates five key opportunities to improve the effectiveness of flash flood warning systems:

- the need for clear roles and responsibilities for BoM and other warning system players in the delivery of warnings and forecasts
- ensuring the financial and technical capacity of local government to implement a warning system
- the opportunity to extend the warning lead time through community and agency access to weather radar information

- awareness among at-risk communities of risk and consequences
- use of pre-scripted warnings to provide information worded to yield appropriate responses and to eliminate warning delays due to drafting (Victorian Review, p. 47).

4.3.2 Emergency management framework

The overall aim of emergency management is to help reduce loss of human life, illness or injury to humans, property loss or damage, and damage to the environment in Queensland (Queensland Inquiry interim report, p. 258); and to minimise the threat and impact to people, property and the environment in Victoria (Victorian Review, p. 18). These aims are articulated in the *Disaster Management Act 2003* (Qld) and the Victorian State Flood Response Plan respectively.

The emergency response in both Queensland and Victoria revealed that current arrangements are suitable for a modest flood event but cannot cope with an event on the scale of the 2010–11 floods. There were communications failures, shortages of personnel (both in terms of numbers and training) and a lack of suitable equipment and facilities. This hampered control and management of the emergency as well as operational response.

Queensland's emergency management arrangements do not cater for managing large-scale flood events (Queensland Inquiry interim report, p. 118; Queensland Inquiry final report, pp. 408–10). The Victorian Review suggests that Victoria's emergency management framework is similarly flawed. It highlights the lack of capacity and capability of Victorian emergency management agencies to handle rapid-onset, large-scale events of long duration (Victorian Review interim report, p. 17; Victorian Review final report, p. 117). Handmer and Dovers (2007, pp. 92–7) characterise such events as 'complex', and this fits well with descriptions of possible extreme weather events caused by climate change. Review findings on improving the management of large scale emergencies may therefore hold some important lessons for climate change adaptation.

Capability and capacity issues

Climate change is expected to place increasing demands on emergency services (Gissing et al. 2010). The response to the 2010–11 floods demonstrated significant lack of capacity. Some issues, including a lack of suitable training and equipment, are implicated in deaths.

- Website and call centre use surged, sometimes causing systems to fail completely (Brisbane Review, pp. 34–5; Victorian Review, p. 199; Queensland Inquiry interim report, pp. 180, 185–6).
- There was a lack of staff numbers and trained staff (Victorian Review, pp. 118–23; Queensland Inquiry interim report, pp. 169–79, 187). In complex emergencies of long duration, covering wide geographic areas, adequate numbers of response staff are needed, including allowances for staff to work in shifts. The Victorian Review notes that the SES and fire brigades compete for the same pool of volunteers, and often have overlapping membership. While increasing volunteerism is one approach, there are simply not enough people in some rural areas to sustain community-based volunteer organisations.
- There were an insufficient number of facilities for flood incidents (Victorian Review, p. 132).
- Equipment was sometimes lacking or unsuitable (Victorian Review, p. 200; Queensland Inquiry interim report, pp. 174–80).

Solutions included upgrading IT or communication systems to improve capacity or overflow function, and reduce congestion and data entry (Victorian Review, pp. 397–9; Queensland Inquiry interim report, pp. 177, 181); the use of a static website to reduce

demand on processing power and bandwidth (Brisbane Review, p. 34); capacity assessment (Victorian Review, pp. 124, 135, 183; Queensland Inquiry final report, pp. 406–7); prior learning recognition (Queensland Inquiry final report, p. 418); improved volunteer recruitment and resourcing (Queensland Inquiry interim report, pp. 179–80); and improved training in terms of both quality and opportunities available (Victorian Review, pp. 118–22; Queensland Inquiry interim report, pp. 120–1, 167, 172, 179, 187). Another measure to boost response capacity is implementing the 'all hazards, all agencies approach', discussed in detail in the next section.

All hazards, all agencies approach

An 'all hazards, all agencies' approach to emergency management aims to deal with all types of emergencies, varying from natural disasters to terrorism or pandemics, using the same management arrangements. It also aims to integrate arrangements between all agencies involved, including NGOs. This approach has long been used in Australia for emergency management. It was promoted in the 'Commonwealth counter disaster concepts and Principles' in 1989, and continues to be a key concept in the current Australian Emergency Manual Series (EMA 2004). Despite its long history, evidence from the reviews shows this objective has not yet been achieved.

The Victorian Review very strongly supports strengthening the 'all hazards, all agencies' approach as being particularly valuable for large-scale emergencies such as the 2010–11 floods. Large emergencies are beyond the response capacity of any single agency (Victorian Review, p. 119; Queensland Inquiry interim report, pp. 178–9). It is impractical to maintain large numbers of trained flood responders with the capacity to cope with a 1 in 100 year flood if they are not used for years between events. However, if all agencies are able to work together to address any hazard (not just the one with which they are primarily tasked), their joined-up capacity will increase the ability to cope with large-scale emergencies. While the Queensland Inquiry less overtly promotes 'all hazards' as a concept, the emergency response issues revealed by the inquiry, as well as the recommendations it makes, overlap with those of the Victorian Review.

There are a number of barriers to implementing this approach. These include lack of interoperability of systems used by different agencies, poor governance and legislative barriers (Victorian Review, p. 146).

Poor *governance* can hamper an integrated approach to emergency management. In Victoria, there is no single official responsible for all control agencies (p. 112). State-level governance is extraordinarily complex, comprising of an emergency management council (VEMC) and 40 committees. An unfinished review of the VEMC in 2009 found the *Emergency Management Act 1986* (Vic) provided the VEMC with no clear role, intent, function or purpose. The council is too large to be effective, meets infrequently, does not ensure a strategic whole-of-sector approach and does not hold other committees to account (pp. 115–16).

The 40 committees are intended to ensure comprehensive and integrated emergency management. They cover specific emergency types, and some committees provide broader strategic direction for impacts that extend beyond one portfolio. However, the committees are not supported by any document mapping out their roles, relationships or reporting lines. Their number leads to difficulties in ensuring effective representation on all of them, and a number of committees have been inactive for several years. There are problems with lack of coordination, accountability, compliance and outcome productivity. Some committees have overlapping responsibilities and need greater definition in their respective roles. The review recommends a reconfiguration of the VEMC and committees, and suggests major reform of emergency management arrangements is needed (pp. 115–17, 147–9).

For more local response bodies, there was sometimes variable performance and lack of understanding of roles (Victorian Review, pp. 135–6, 186; Queensland Inquiry interim report, p. 115). In some cases, there was also a duplication of roles (Victorian Review, p. 202) and a lack of compliance with existing procedures (Victorian Review, pp. 138–9). To ensure appropriate roles and accountability, the Review recommends revision of roles, training exercises, oversight by an independent body and the development of templates and practice notes.

When there is a widespread emergency, there need to be mechanisms to *scale up*, enabling involvement of other agencies and strategic coordination. In Victoria, there are 'all hazard' scalable command and control arrangements in place that can progress from localised incident management through to regional and statewide tiers of management. The progression to each tier is expected to be provided by escalation triggers – for example, weather conditions or depletion of resources. In Victoria, the SES is the designated agency charged with controlling the management of flood incidents. However, the Review reports that VICSES lacked scale-up or trigger mechanisms (pp. 108, 111, 124). While arrangements in Victoria aim to ensure scalability, a number of impediments remain, such as interoperability difficulties and legal impediments to using other agency staff in control roles (p. 124).

The Queensland SES is the principal response agency for flood. Unlike Victoria, the Queensland SES is purely a response agency, not charged with managing emergency response or tasking other agencies. In Queensland, this control function is the responsibility of disaster-management groups chaired by the police service, which are tiered along similar state–district–local lines as Victoria: see interim Queensland Inquiry, pp. 112–15 for an outline of Queensland emergency management framework arrangements.

The final Queensland Inquiry report reveals that the SES has a lack of command structure above the level of the local controller. This creates uncertainty about who should direct large-scale SES operations that involve many units, and how to manage tasks when local capacity is exceeded. It also poses problems for the command of SES units deployed outside their areas. The reason for this lack of command clarity lies partly in the principle of shared responsibility for the SES between local and state governments. Efforts have been made to address this via memoranda of understanding (MoU) between councils and Emergency Management Queensland (very few of which have been executed), and through operational directives. However, these directives exceed the authority provided by legislation *Disaster Management Act 2003* (Qld). Other governance issues include a lack of clarity of reporting lines for incident controllers in large-scale emergencies and a lack of revision of SES arrangements following council amalgamations. Assessment of the fire and rescue service – also involved in flood response – revealed issues with undocumented procedures and planning deficiencies. Various recommendations include legislative amendments, clear roles and reporting responsibilities, improved procedures, including capacity assessment and processes relating to resourcing requests (pp. 402–5, 407–14).

Interoperability issues were significant in both Victoria and Queensland. In Queensland, besides the SES, other response agencies involved in floods include the police service (leading disaster response of all hazard types through its disaster-management groups), the fire and rescue service (responsible for rescue, including swift water) and the ambulance service (Queensland Inquiry interim report, pp. 114–15). In Victoria, as seen above, VICSES is the nominated control agency for floods. It works with eight other officially recognised key support agencies. However, the number of agencies actually involved is actually greater (e.g. the police service, responsible for water rescue, is not among the listed support agencies – pp. 112–13). Large-scale emergencies require all agencies involved to have compatible systems so that they can communicate with each

other, exchange information and manage resources via a common system. Some examples of interoperability failures include:

- For emergency calls, computer-aided despatch systems were incompatible; ESCAD is used by the fire and rescue service and SES and ESCORT is used by police (Queensland Inquiry interim report, p. 184; Queensland Inquiry final report, pp. 397–8).
- Agency equipment was not purchased with 'all hazards' in view, so those charged with water rescue were not equipped with waterproof hands-free radios and rescue vehicles were not designed for flood conditions (Queensland Inquiry interim report, pp. 142, 174–6).
- Emergency services don't have interoperable radio communications or dedicated broadband data networks (Queensland Inquiry final report, pp. 398–9; Victorian Review, p. 126).
- Response agencies use different systems for collecting and analysing information, and were not easily able to share information – especially large documents containing maps (including incident action plans). Sometimes these were unable to be sent electronically and needed to be physically transferred by USB (Victorian Review, pp. 127, 133).
- Within the State Control Centre, there were seven different and incompatible incident-management systems and five different and incompatible teleconferencing systems (Victorian Review, p. 128).
- Resource-management systems were not compatible, meaning other agencies were not aware of personnel deployed or their requirements. No single system caters for all multi-agency operations (Victorian Review, p. 126, see also Queensland Inquiry interim report, pp. 162, 166).
- Software was incompatible (Queensland Inquiry final report, p. 417); IT systems were incompatible; data systems between key agencies were not integrated so information had to be sent via email rather than stored on a common drive (Victorian Review, p. 128).
- Facilities for emergency response were not suitable for 'all hazards', and could be flooded or not equipped for SES requirements (Victorian Review, pp. 132–3; Queensland Inquiry interim report, p. 161; Brisbane Review, p. 38).
- Records management systems are inadequate and inconsistent between agencies, compromising accountability (Victorian Review, p. 127).
- During the floods, firemen performed flood rescues, but they are not officially recognised for this role (in Victoria) and are not equipped or trained for it (Victorian Review, pp. 121, 142; Queensland Inquiry interim report, pp. 178–9).

The reviews recommend various solutions, such as a procurement gateway process to ensure all new systems and equipment are interoperable between relevant agencies, common databases, universal portals, use of broadband networks and compatible procedures (Victorian Review, pp. 126–9; Queensland Inquiry interim report, pp. 162, 166, 184, 197; Queensland Inquiry final report, p. 399). The Victorian Review argues for a need to maximise the flexibility and united capacity of CFA/VICSES (p. 145). The reviews, while state focused, note interoperability issues across state borders (Victorian Review, p. 170; Queensland Inquiry interim report, p. 203). An extension of interoperability recommendations could ensure national compatibility.

Despite interoperability deficiencies, measures have been taken in both states to improve interoperability and an 'all hazards' approach. Victoria uses the Australasian Inter-Service Incident Management System (AIIMS) to manage incidents of 'all hazards' across services (Victorian Review, p. 58). Queensland is currently developing the All Hazards Information Management System for use by all levels of disaster-management

groups and between disaster management agencies. Its function is to collect data and track assistance (Queensland Inquiry interim report, p. 166).

Despite having a common incident-management system, lack of familiarity with how incident management operates under different types of emergency events was an issue during the response, causing confusion about roles and responsibilities. The Victorian Review recommends joint agency exercises to remedy this (pp. 126, 135, 144). Regular joint agency exercises for practising coordination and operating procedures were also recommended by the interim Queensland Inquiry (pp. 120–1).

In Victoria, there are legislative impediments to the 'all hazards, all agencies' approach in that the *Emergency Management Act 1986* (Vic) and the *VICSES Act 2005* (Vic) only allow control functions to be filled by the designated control agency, VICSES, in the case of flood. However, VICSES is only a relatively small agency, comprising 125 staff and 5500 volunteers across the state, and according to legislated arrangements only staff are able to exercise control functions (Victorian Review, pp. 139, 145). This meant that VICSES was unable to appoint experienced staff from other agencies to fill these needs when its capacity to control the flood was exceeded. In some localities, other agencies (notably fire brigades or municipal bodies) assumed de facto control.

The review identified other legislative issues, notably a lack of legal authority given to the VICSES to undertake activities necessary in floods, such as removal of levees, and powers to enter private property or remove water diversion installations. The review argues that, together, these issues suggest the need for a comprehensive review of legislative arrangements, of both the *Emergency Management Act* and agency-specific legislation to ensure joined-up capacity between all agencies (pp. 139–41).

Resourcing arrangements

Local councils had varying capacity to cope with the floods, and less well-resourced councils struggled. Support is needed from state governments in terms of planning, risk management and training (interim Queensland Inquiry, pp. 115–20, 160–1). Issues with reimbursement of emergency response activities following a disaster are also an issue, and the Victorian Review recommends improved arrangements for disaster financing (pp. 209, 212–13).

Resourcing of the SES was a particular problem in Queensland. Funding to support the SES is supplied by both state and local governments. However, funding of some units is grossly inadequate, and volunteers have to supplement their income with fundraising activities, which supplies up to 40% of their annual operating budgets. Fundraising obligations have meant that SES volunteers have had to forego training opportunities and become burnt out. Emergency Management Queensland, which administers resourcing on behalf of the state government, does not assess the relative financial needs of SES units, and does not monitor the amount of money each council spends on the SES. The Inquiry observes that 'shared responsibility for the SES really comes down to shared financial responsibility'. It sees a need to revise resourcing arrangements, and suggests that a 'fundamental re-working of the SES model may be required' (Queensland Inquiry final report, pp. 415–18).

In both Queensland and Victoria, council amalgamations have taken place; and in Victoria, there have also been changes in procurement processes, but arrangements for emergency management have not simultaneously been adjusted (Victorian Review, p. 201; Queensland Inquiry final report, pp. 413, 416–18). In Victoria, councils are legally responsible for planning and coordinating council resources for emergency response. However, since the *Emergency Management Act* was passed in 1986, competitive tendering has been introduced, resulting in a transfer of services and equipment to the private sector. This means these resources are no longer available to councils for

emergency response. The Review recommends a revision of the role and responsibilities of local government in line with current arrangements, ensuring the capability and capacity of each local government is taken into account for emergency management arrangements (pp. 200–4).

4.3.3 Essential infrastructure

Protection of essential infrastructure and its performance during the floods was covered in all of the reviews. Essential infrastructure includes electricity, telecommunications, sewerage and stormwater systems, transport networks and supply facilities. The capacity for infrastructure to withstand flood is tested most during large-scale emergencies when these services are least dispensable.

One point consistently recognised in the reviews is the interdependency of some of these services and the increasing reliance placed on them for emergency response. This is particularly the case for electricity and telecommunications. The interim Queensland Inquiry report notes that 'although lack of power did not prevent activities, it limited their timeliness and effectiveness' (p. 161). In some places, emergency response was hampered by power outages, leading to a complete lack of means of communication between key response personnel for some periods during the floods (Brisbane Review, p. 37; Queensland Inquiry interim report, p. 161). Lack of power can compromise warnings and the provision of flood information to the community. According to the final Queensland Inquiry report, 300 000 customers in Brisbane and Ipswich lost power during the floods (p. 240). Electrical supply also impacts on food and water supplies, and on sewage treatment (Victorian Review, pp. 187, 190; Queensland Inquiry final report, p. 221).

Causes of electrical failures and solutions are discussed in reviews. The main issue is that the siting of power substations is not always on appropriately high ground (see Section 4.1.2). However, electricity companies are constrained by legal obligations to provide power, regardless of where development is constructed – even if it is on low-lying ground (Queensland Inquiry final report, p. 245).

Design features can be incorporated to improve flood resistance. Retrofitting of power stations to make them more resilient, including raising the level of some equipment, and the placement and design of electrical infrastructure in multi-level buildings (see Section 4.1.3). The Queensland Inquiry report shows that protection measures were undertaken just prior to the flood, such as wrapping telecommunication infrastructure in plastic, sandbagging and bolting steel plates to walls of exchanges to prevent floodwater intrusion (p. 251). Solutions also include contingency planning, which can include the use of battery-operated communication devices, as well as alternative warning methods that do not require electricity supply, generators and mobile substations (Queensland Inquiry interim report, pp. 129, 161; final Queensland Inquiry, pp. 239–46).

Damage caused by power outages can sometimes be greater than that caused by the flood itself. (Victorian Review, p. 187). In Victoria, this happened at Charlton when the substation was inundated and a similar situation threatened at Kerang. The Victorian Review reports that, had the Kerang substation flooded, it would have caused 20 000 people in north-west Victoria to be without power (pp. 187–8). The council and the incident control centre (emergency response) had some difficulty persuading the provider to take appropriate steps to protect the substation (reinforcing levees around it). The responsibility for ensuring that power providers take adequate steps to protect supply during emergencies is unclear due to privatisation of power companies and complex Victorian state and Commonwealth arrangements (whereby the Department of Primary Industries, the Australian Energy Market Operator and the National Electricity Market all have responsibilities, the state having divested some of its powers via MoU). However, the

Review concludes that the state needs to play a more active role in ensuring greater protection for key infrastructure against natural hazards. In particular, it needs to ensure essential services have appropriate risk mitigation strategies in place (pp. 190–1).

4.3.4 Isolation, evacuation

If climate change leads to more severe flooding of longer duration, isolation and the need for evacuation and relief can be expected to affect a greater number of people. More intense precipitation events could result in less warning time for evacuation. Larger events could increase the number of communities affected and complicate the coordination of resupply. Any increase in the duration of flood events would also mean more prolonged isolation or evacuation to alternative accommodation.

Planning measures to accommodate flood levels, such as raising the level of development sites with fill, increased habitable floor height and the rebirth of the 'Queenslander' housing design (house on stilts) could also contribute to isolation, as surrounding roads and evacuation routes can become flooded before people are aware they are cut off. The final Queensland Inquiry report discusses the issue of properties built on land higher than surrounding access roads in its section on 'ant hills' (p. 173). Measures to reduce isolation include improved design of transport infrastructure, such as raising its height – although the final Queensland Inquiry suggests that this retrofitting solution is costly and therefore difficult to achieve (see Section 4.1.3).

The interim Queensland Inquiry report discusses measures that can be taken to improve emergency management responses to isolation. Chief among these is improved planning for isolation by local governments. For example, when flood conditions are expected, an assessment can be made of locally available aircraft, their operating costs and their capacity (p. 118). Planning by local councils can include identification of communities susceptible to flooding, possible evacuation routes and centres (including identification of places that served as informal evacuation centres during the recent floods), organisation of locally based emergency sub-groups, and communications and resupply arrangements (pp. 163–4).

Similarly, measures recommended to improve evacuation primarily involve planning by local councils. Options to improve evacuation planning include identification of characteristics for suitable evacuation centres, suitability of centres for flood as opposed to other hazards, better involvement of charities in disaster planning, improved processes for handling donations, identification of individuals who may need assistance and registration of evacuees. Issues relating to informal evacuation centres in isolated communities were identified, including a lack of liability cover for individuals who made their premises available and a lack of recognition of authorities for resupply purposes (Queensland Inquiry interim report, pp. 192, 195; Victorian Review, pp. 174–5; Brisbane Review, pp. 38, 44–7).

Reviews also look at the role of education in improving response to flooding by communities, improving household preparation and planning for isolation and/or evacuation (Victorian Review, p. 85; Brisbane Review, p. 33; Queensland Inquiry interim report, pp. 121–3).

Some sectors of the community are more vulnerable to isolation than others, and have more difficulty evacuating. The interim Queensland inquiry notes that hospitals and aged care facilities in particular need adequate warning time, as it is a lengthy process to evacuate them (p. 193). It does not help that these facilities and facilities of other vulnerable groups such as child care are sometimes situated in areas that are more flood prone (Queensland Inquiry final report, pp. 149–50, 174). Recommendations in the

interim Queensland report include improved evacuation planning (pp. 188–97), and the final Queensland report recommends improved siting and access/evacuation routes (pp. 148–51).

Mechanisms are discussed in the reviews for communicating with isolated individuals and communities. The Queensland Inquiry discusses conduit of information through local sub-groups and the usefulness of radio (p. 131). The Victorian Review also mentions the potential of using social media for this purpose (pp. 97, 102).

4.3.5 Mining activities

Only the final Queensland Inquiry report addresses the impact of the flood on mining activities and off-site effects of mines during the floods. The chief issues identified are the release of contaminated material and damage sustained by the flooding of mines. If climate change causes more frequent large-scale flooding, impacts on economic activities such as mining may reduce society's ability to recover. Water contamination from mine discharge may exacerbate damage to marine and freshwater ecosystems already under threat from climate change. Adaptation to climate change needs to assist robust primary industries that are able to accommodate flood events and that need to minimise the off-site impacts of large-scale flood events.

The effect of the floods on the mining enterprises was significant, with production restricted or entirely closed down at 85% of coal mines. By May 2011, the industry had only recovered to 75% of its pre-flood output. This resulted in royalty losses to the Queensland state government and a loss of $5.7 billion in Queensland's gross state product, a sum greater than the entire $5 billion cost of the flooding estimated by the Queensland Reconstruction Authority (pp. 32, 350). Arguably, this has implications for the ability of the state to finance recovery after the flood.

Queensland mining activities are not assessable development under the SPA (p. 153). Legislation relevant to water management by mining activities falls under the *Environmental Protection Act 1994* (Qld). Mines need water to undertake mining activities, and years of drought meant that some mines were deliberately designed to maximise the capture of run-off.

Factors that contributed to mine damage during the 2010–11 floods included a lack of awareness of BoM seasonal forecasts, completion of site inspections too late in the season to implement preparation measures and teething problems for management arrangements designed to enable controlled discharge of excess water during floods. The latter was primarily an issue for coal mining enterprises in the Fitzroy River Basin, which operate under the Fitzroy Model Conditions, introduced in 2009. The principal contaminant from coal mining is salt, and the current assessment process to enable discharge of excess water during flood is unwieldy. While a rigorous assessment process is important to ensure safety, some of the more than 100 criteria were 'seemingly impossible to answer' and did not ensure consistent decision-making. Approval delays caused some mining operators to miss a brief window of opportunity where it would have been safe to discharge mine-affected water. The Inquiry notes that a revision of the Fitzroy Model Conditions has taken place since the floods. The Inquiry also recommends legislative amendments to clarify provisions and to enable pre-emptive approvals; and to introduce improved assessment processes, procedural guides and their availability to mining operators. More comprehensive monitoring of sensitive ecosystems to determine the impact of contaminants on them are also recommended (pp. 350–69).

A significant issue for contamination of waterways during flood events was the lack of responsibility by any state agency for all the state's 15 000 abandoned mines

(particularly those on privately owned land). Abandoned mines pose significant water quality risks, and during floods they can release acids, sediment and chemicals such as cyanide and copper compounds, due to seepage or overtopping of tailings dams. These contaminants impact on human, livestock and wildlife health. The current abandoned mines program primarily covers the 3000 mines on state-owned land, and is greatly hampered by a lack of resourcing. The Inquiry identified a need for improved data collection about all abandoned mines, systematic risk assessment including flood risk, and a risk-based method of prioritising rehabilitation (pp. 369–75).

4.4 Recovery

Floods are Australia's most expensive natural hazard, costing $377 million annually (average between 1967 and 2005) (BITRE 2008);(The National Flood Risk Advisory Group 2008). Review reports estimate that the recent floods cost Victoria $1.3 billion and Queensland $5 billion[6] (Victorian Review, p. 21; Queensland Inquiry final report, p. 32).

Climate change can be expected to increase the cost of flood damage, as events are likely to increase in both severity and frequency. Increases in damages may also be caused by flooding happening in locations not previously believed to be flood prone, where buildings are not designed to be flood resistant. An IPCC technical paper suggests that average annual flood damages in three Australian drainage basins are likely to increase between fourfold and tenfold under doubled CO_2 conditions (Bates et al. 2008, p. 46).

While climate change is one factor likely to increase costs of recovery, increasing wealth (leading to increased losses) and population increases (which can cause pressure to develop in unsuitable locations) are also responsible for increasing costs (Bates et al. 2008, p. 37). This cost ultimately has to be borne by society, in the form of increased insurance premiums, charity or through taxpayer-funded grants and subsidies.

4.4.1 Insurance

Recovery and the ability to 'bounce back' are key factors in resilience. Insurance is the primary means via which private individuals and businesses can finance recovery from disasters such as flooding (Trowbridge et al. 2011, p. 20; Victorian Review, p. 166).

The reviews cover insurance matters to varying degrees. The Brisbane Review only covers recovery issues in the immediate aftermath of the floods, and does not include longer term insurance matters. Moreover, it is primarily concerned with the performance of the Brisbane City Council rather than other organisations. The terms of reference of the Victorian Review address the adequacy of recovery arrangements. However insurance is not explicitly specified, and the Victorian Review determined it was outside its scope (p. 165). However, it did include some observations regarding insurance that are supported by other sources – such as the protracted assessment process and lack of product equity.

Out of all the reviews, the final report of the Queensland Inquiry covers insurance issues most comprehensively, but is confined by its terms of reference to examining the insurance industry's performance in meeting its obligations following the 2010–11 floods. One key finding in this regard is that while many people thought they were covered for flood, the wording of insurance policies actually excluded flood. The issues examined by the Queensland Inquiry include timely and appropriate determination of claims, the assessment process and the disputed claims process. Wider issues of insurance affordability and availability are not addressed (p. 282). These issues are covered in the

[6] The Queensland figure appears to be an under-estimate. The Queensland Reconstruction Authority reports 2010–11 damages of $6.8 billion to state assets alone, not including private or indirect costs (Queensland Reconstruction Authority 2012, p. 1).

National Disaster Insurance Review, completed in September 2011 (Trowbridge et al. 2011). It is referred to in this section as the 'Insurance Review'.

Timeliness and a standard flood definition

Speed is a significant factor in successful recovery. The earlier transition to recovery can be accomplished, the better (Victorian Review, pp. 166, 178). The Victorian Review discusses significant time delays in processing insurance claims and how this impacted on recovery. It cites examples of people having to delay clean-up for weeks, sometimes while living in flood-damaged properties, before insurance companies could carry out assessments. Some properties were subject to three or more assessment visits (pp. 165–6).

Evidence in the Queensland Inquiry clearly points to the process of determining the *cause* of flood as a significant factor delaying the determination of claims process. Among the insurers studied in the inquiry, only Suncorp provided automatic flood cover, regardless of whether flooding was caused by stormwater, riverine flooding or flash flood. It had the fastest response to claims determination, with 98% of claims being decided in 10 days or less (p. 295). This contrasts to the time taken by most other insurers, which excluded riverine flood from their policies. These insurers had to undertake complex assessment processes, requiring hydrological studies, assessment reports and other evidence to be collected and analysed to determine the cause of the flood damage. For these insurers, an average of only 19% of claims was decided within the 10 days or less period. Some 61% of claims with these insurers were determined within two months (the majority in the one- to two-month period).

The Insurance Review recommends a standard flood definition that includes riverine flood (p. 105). The benefits of this would be increased availability of flood coverage and a speedier process for determining claims. Conceivably, this would also cut assessment costs for insurers. The Insurance Review does not suggest extending this definition to flood damage caused by sea level rises or storm surge (p. 82).

Insurance industry capacity

The Queensland Inquiry points to the high number of claims impacting on the capacity of insurance agencies to administer claims promptly. This is also a finding of the 2011 General Insurance Industry Survey (Parameswaran et al. 2012, p. 3). If frequency of large events (flood as well as bushfire) is expected to increase, insurance industry capacity is a consideration that is relevant to recovery from events exacerbated by climate change. Insufficient staffing levels and expertise can delay claims assessment and impair communications with policy-holders, causing stress, dissatisfaction and an increased number of disputed claims (pp. 302–4). It is likely that the new flood definition will go some way towards resolving this.

The capacity of the industry to pay out large claims has been an issue in the past, but has not been raised in recent reviews, suggesting that current underwriting processes are effective.

Assessment processes

The Queensland Inquiry also analysed the assessment processes used by insurers to handle bulk claims, relying on area hydrology reports (rather than site-specific reports) to assess claims in a timely manner (p. 305). The use of this evidence and its corroboration with assessor reports, policy-holder accounts and aerial photographs was generally found appropriate. Site-specific hydrology reports were only obtained if evidence was not consistent or in the event of a dispute. No significant issues were found with the appropriateness of this approach. As above, the need to obtain and analyse hydrology reports may be less of an issue with the more comprehensive flood definition.

Nevertheless, it illustrates ways in which assessment processes can be bulk-handled to improve timeliness.

Availability and affordability

There are potential issues with increasing availability and affordability of flood insurance. If not implemented carefully, it can have the unintended effect of encouraging people to build in flood-prone areas, knowing that they will be able to recoup the costs of recovery (Trowbridge et al. 2011, pp. 3, 38, 84; Handmer & Dovers 2007, p. 84). The Insurance Review includes measures to prevent this. It recommends that even if premiums are discounted for affordability reasons, they must continue to reflect relative flood risk. Discounting would be phased out over time, but would allow people time to adjust to paying the full costs of flood risk. It also recommends that only existing homes be eligible for premium discounting to address legacy issues, and that any new development on floodplains should be ineligible for discounted premiums (pp. 38–40). For new developments, insurance would be available but would be priced according to risk with no premium discounts. This pricing signal may help to discourage development in flood-prone areas. For high-value properties, the size of discount available would be limited, in recognition of the fact that high income earners have more ability to pay higher premiums (pp. 40–1).

The review proposes that discounts be enabled via reinsurance by the Commonwealth, rather than through cross-subsidy by policy holders in areas not at risk of flooding. State governments would be required to share costs to ensure they have a continuing incentive to mitigate flood risk (p. 64). A more recent report by the Productivity Commission argues that the costs of government interventions such as underwriting would outweigh the benefits, and recommends against subsidising premiums, finding that this would impose a barrier to effective climate change adaptation (Productivity Commission 2012).

The Insurance Review recommends that flood mitigation activity be encouraged by taking implemented measures into account in insurance flood-risk assessment (pp. 38, 67). The ability of the insurance industry to provide incentives for mitigation is evident in a recent case where Suncorp decided to raise premiums for existing customers significantly, and to refuse to supply new insurance policies in the towns of Roma and Emerald unless the councils agree to undertake mitigation measures. These measures include the construction of levees, improved development planning, building standards and drainage works. Suncorp's demands were a consequence of significant losses for the company, with flood damages and rebuilds occurring in these towns for three years in succession (Fanning 2012).

Also relevant to mitigation, the Insurance Review suggests that providing cash settlements is an option that allows people to relocate – or, alternatively, gives owners control over hiring their own builders and rebuilding to improved design (p. 97). While enabling relocation would be an excellent outcome, without other interventions this would not prevent vacated land from being used for the same purpose by someone else.

Flood information

The Insurance Review recommends increasing the availability of flood mapping and flood risk information (including mitigation measures such as building design) via a central repository. This information would be available for flood-risk assessment and management by insurers, private citizens, councils and developers. It would also assist insurers to appropriately price insurance premiums and assess underwriting requirements (p. 67). The review recommends that governments provide legal indemnity for the provision of this information (p. 70). These recommendations reflect viewpoints taken in the Queensland Inquiry, Victorian Review and Brisbane Review.

Vulnerability

The insurance review recognises that those who have less income are more susceptible to being uninsured or under-insured. This is for both affordability and cash-flow reasons. Having fewer assets, they are also more likely to have trouble restoring assets that were damaged or destroyed (p. 86). Measures suggested to assist cash flow include insurance being included in rent and Centrelink programs to enable regular small payments instead of one large annual bill. Government subsidies are suggested as one approach to address affordability of insurance for vulnerable people, but this is not analysed in depth (pp. 86–8). The review does not examine the relative likelihood of different sections of society to be located in flood prone areas, or how this impacts on insurance affordability for these groups.

4.4.2 Recovery arrangements

Administrative processes

Administrative issues included the processing of individuals needing assistance, the assessment of impacts to inform recovery operations and clarity of clean-up responsibilities.

The registration of people affected by the floods was inefficient, requiring people to provide the same information multiple times to different agencies (Victorian Review, p. 171; Queensland Inquiry, p. 195). A single point of information-collection was recommended to register individuals and plan the delivery of recovery services. Perceptions that privacy legislation prevented information-sharing were overstated, and the Victorian Review found that existing provisions in the *Emergency Management Act* and the Information Privacy Principles provisions enabled sharing of information during and after emergencies. Issues could be overcome with adequate pre-planning and development of a National Registration and Inquiry System information-sharing protocol.

In Victoria, assessment of roads and infrastructure needing repair was the responsibility of VIC Roads. Capacity was stretched, both for assessment and repair. Due to the widespread nature of the damages, there were significant issues with the availability of plant, contractors and material (Victorian Review, p. 200). To speed recovery, one council in Queensland allowed landowners to undertake temporary repairs so they could access their properties to transport supplies or livestock. Approval was granted via email on the basis of requests and photographs, with provision for reimbursement of costs. The Inquiry recommends that such provisions be more widely adopted (Queensland Inquiry interim report, p. 203).

In Victoria, responsibilities for clean-up were sometimes unclear, and in some cases no one took responsibility. Areas of contention included boundaries between private driveways and public roads, roadside drains, bridges and debris on creek banks. The Victorian Review questioned the capacity of those assigned clean-up responsibilities, and suggested a review of legislation and policies. Responsibility also needs to be made clear in a publicly available guide (pp. 163–5). The responsibility for rapid impact assessment activities used to inform recovery activities is another area of dispute, particularly in view of capacity issues of control agencies such as SES. Current documentation does not specify which agency is responsible for collecting and analysing information for a post-impact statement (p. 167). A clarification of the purpose, roles and responsibilities, and processes is needed (p. 168).

In both Victoria and Queensland, there were difficulties involved in coordinating volunteers. The Brisbane Review demonstrates that there are opportunities for volunteer involvement in clean-up that need to be better anticipated and planned. However, management of these volunteers was an issue. Prior to the 2010–11 floods, the

Brisbane Disaster Management Plan had no strategy for managing volunteers. The Council and Volunteering Queensland were overwhelmed with between 50 000 and 60 000 volunteers (both members of the public, and specialist trade volunteers and people with equipment) to assist with clean-up operations. The council quickly had to develop a strategy for registering volunteers, matching resources to need, transport strategies for volunteers to minimise congestion and offering vaccinations (Brisbane Review, pp. 47–50). Some of the issues regarding the use of volunteers need to be thought through and resolved prior to emergency situations, including liability issues, training and supervision (Handmer & Dovers 2007; FEMA 2012, p. 15). Preplanning and liability issues relating to volunteers are also discussed in the Queensland Interim Report (pp. 192–3) and the Victorian Review final report (pp. 168–9).

Financing recovery

Government grants processes are covered by the Victorian Review (pp. 176, 207–15). Financial assistance is supplied by the Commonwealth through the Natural Disaster Relief and Recovery Arrangements and through the Victorian government through the Natural Disaster Funding Arrangements. These primarily reimburse emergency costs of response agencies and fund recovery activities of local councils. They also provide loans or grants to individuals and businesses.

The review found 'no widespread dissatisfaction expressed with the adequacy of the monetary amounts of financial assistance provided to individuals' (p. 208). However, there are issues with a lack of information and complexity of grants processes for both individuals and councils that need to be addressed.

Local councils are also hampered by a lack of assurance that emergency response and recovery expenses will be reimbursed (p. 209). Provisions for betterment, requiring pre-approval and cost-benefit analysis (see discussion of betterment in an earlier section) also delay recovery for councils seeking to rebuild to more resilient standards (p. 211). Improved assistance arrangements are recommended, including upfront funding for local councils of 50% of expected costs – possibly via trust fund – as well as inclusion of early relief and recovery packages in Commonwealth and state arrangements, and improved reimbursement processes (p. 213).

4.5 Literature review findings

Climate change can be expected to increase both the likelihood and consequences of flood events, and can thus be viewed as a factor that multiplies risks. Climate can no longer be assumed to be stationary, and historic averages that form the basis of 'likelihood' are no longer valid. This is not only an issue for coastal areas due to sea level rise; changing precipitation patterns are also expected to worsen inland flooding. The Victorian Review characterises the recent floods as being large in scale, protracted, and often having a rapid onset. This fits well with climate change flooding scenarios, suggesting that any recommendations resulting from this event – from either state – should help us to adapt to similar climate change flooding anticipated in the future.

Although the reviews cover impacts of climate change for specific issues, such as liability, none of the reviews quantifies future flood risks that can be anticipated due to climate change (see Section 2). This explains the seeming under-estimation of future risks and adaptation needs. This is nowhere more apparent than in the Queensland Inquiry, which seems to assume stationarity of weather patterns in its discussions on flood mapping and building codes for development on land that has been identified as flood prone. The reviews, as the very word suggests, looked back at a single severe flood event rather than looking forward to comprehensively integrate climate change and other factors such as population changes into their consideration of appropriate measures to minimise future flooding.

The findings of the flood reviews overwhelmingly point to the need for improvements in non-structural measures, such as development planning, production and availability of quality flood information, emergency response management and community participation. All reviews were cautious about recommending structural measures such as use of levees or engineering methods such as flood barriers. Other than the ENRC Inquiry, the reviews paid scant attention to landscape-scale management options to address flood impacts, which might comprise natural flood control and reduce society's vulnerability to floods. The only two incidences identified were resilient farming systems (discussed only in the context of recovery grants) and riverbank slumping caused by vegetation clearance. Neither issue yielded any recommendation. Yet such management options are very much a part of 'non-structural' options to manage flood.

Need for improvement arose repeatedly in the following areas:

- governance, policy, integration and coordination
- legislation
- clearer roles, responsibilities, accountabilities, aligning with capability and capacity
- independent oversight, review and audit
- procedures, guidelines, templates
- planning and risk assessment
- resourcing (amount and mechanisms)
- information collection, analysis and dissemination
- communication
- professional training
- community education and participation
- design standards and building codes.

These findings tally with findings reported by others. Godden and Kung (2011) find that the majority of issues for climate change adaptation in the context of flood risk are socio-institutional (p. 11). The Productivity Commission draft report, *Barriers to Effective Climate Change Adaptation*, finds a need to clarify the roles, responsibility and legal liability of local government (including its capacity in terms of resourcing and expertise); a need for localised climate projections; improved land use planning; emergency management arrangements; quality and availability of hazard information; and the need to remove perverse tax incentives and avoid regulatory distortions in insurance. In particular, it notes that the right balance has not been struck between prevention/preparation and response/recovery, with too much emphasis on the latter. The report suggests that building and planning regulations, in particular, have not been well integrated into managing environmental hazards (Productivity Commission 2012). Many of these issues, particularly with regard to policy approaches, legislation, incorporation of climate change into emergency management and land use planning are also identified in the Australian Government's Coastal Climate Change Risk report (Gibbs & Hill 2011).

The government approach to emergency management articulated in documents such as the National Strategy for Disaster Resilience present community participation as an element of increasing importance. Better public information on local risks, emergency arrangements and appropriate response will enable greater self-reliance.

An assessment of which adaptation measures are most cost effective is provided by the Victorian Review. It includes a quote from the Bureau of Transport and Regional Economics, Report 106:

> Reducing flood risk in established areas is costly. It is significantly easier to impose proactive mitigation measures such as land use planning and building standards to minimise further risk before development occurs.
>
> Indeed, compared to mitigation measures that modify the flow of water (such as levees) or response modification (which seek to modify human behaviour through activities such as public education, warning systems and emergency service response), property modification measures are the most cost effective for addressing future risk. They are also 'less expensive, less inequitable and less environmentally intrusive than structural mitigation'. (Victorian Review, p. 191)

The review's comparison of measures raises questions about the efficacy of the government's current community resilience and shared responsibility focus. This community approach relies on the modification of human behaviour, and while improvements in emergency response have been observed in programs like FloodSafe, community resilience also implies a sound understanding of risks and appropriate decision-making at the prevention stage – for example, when buying property or selecting building designs – and this may be harder to achieve.

As well as improving governance, legislation and procedures, the lack of defined roles, responsibilities and accountabilities is an issue that arises regularly throughout review reports. It is an issue identified for emergency management response (e.g. Victorian Review, pp. 112–17, 135–6; Queensland Inquiry final report, pp. 407–14); coverage of warning systems (Victorian Review, pp. 39–40), administrative arrangements for dams (Queensland Inquiry interim report, p. 47); council processes in assessing development applications (Queensland Inquiry final report, p. 199); NGO involvement in evacuations (Queensland Inquiry interim report, p. 194); and recovery arrangements (Victorian Review, p. 163). This is not a comprehensive list of instances where a lack of defined responsibilities was cited as an issue. Where roles and responsibilities are unclear, there is a risk that no one will know who is responsible, no one will accept accountability and activities won't be undertaken. Clarification of responsibilities needs to go hand in hand with assessment of capacity to undertake activities, including staffing, resourcing levels and expertise. Other considerations include conflicting responsibilities and the lack of correlation of administrative and natural geographic boundaries.

Regardless of whether climate change is considered, improved management at all phases of emergency management can only benefit the ability of Australia to cope with future flooding.

5 INTERVIEWS

5.1 Interview methodology

5.1.1 Interview rationale and selection of interviewees

In order to validate findings from the literature review and to gain a more in-depth understanding of issues relevant to climate change adaptation, interviews were conducted with individuals who had experience and expertise in fields relevant to the project. These fields included emergency management, insurance, local government, floodplain management and ecosystem research. Prior to interviews being conducted, the proposed research and accompanying participant information sheet, consent form and topic guide were submitted to the ANU's Human Ethics Committee. This was approved by the Committee on 28 February 2012.

Potential interviewees were selected via a number of processes. The project's End-Users Committee (comprising individuals from the above areas of expertise) were asked to nominate people they felt would be suitable. The project's primary investigator, supervisors and additional investigators also have expertise and contacts in these areas, and contributed to the list of people to be approached.

A draft list of interviewees was provided to end-users at its meeting on 18 May 2012. At that meeting, advice was offered by some members to include interviewees with expertise in ecosystem approaches to flood management. This advice was accepted, and suggested interviewees were approached. The number of interviews was divided roughly equally between the five categories. A further category was later added, consisting of one interviewee (UT#1). This interviewee was selected to provide a private sector viewpoint, and because of their experience modelling rainfall and runoff in highly populated catchments.

5.1.2 Interviewee codes

While participants were assigned a dominant end-user category, it should also be noted that several had extensive experience in more than one area. For example, local government interviewees had experience in engineering aspects of flood management, emergency management and floodplain management and planning within their respective organisations. One insurance professional interviewed had prior experience of flood management in the public sector. Floodplain managers sometimes had experience in research, and so on. Thus the 'category' generally reflects the person's current position or the primary reason the person was selected for interview, and not necessarily their overall experience.

For local government interviewees, both urban and rural municipalities were represented in areas subject to regular flooding. State government personnel from both Queensland and Victoria were interviewed. There were no federal government interviewees, though four interviewees noted that they had previously worked in emergency management agencies at the federal level, one of them for 18 years.

Experience was sometimes focused on one phase of emergency management but for many interviewees encompassed a number of phases (prevention, mitigation, preparation, response, recovery, review). A rough tally indicates about 244 years of experience, though this is likely to be an under-estimate as the number of years spent in relevant positions prior to the current one was not always given. This reflects the research approach, which was intended to be qualitative, not quantitative. This approach was necessary given the short timeframe for the project.

The following interviewee codes were assigned to reflect the end-user category:

EM Emergency Management
UT Urban Utility
FM Floodplain Management
ER Ecosystem Research
INS Insurance
LG Local Government

Each interviewee was given a unique number – for example, EM#1. Codes that include a decimal point – for example, EM#1.2 – indicate that more than one person was interviewed at the same time. Where relevant, the interviewee's state is included in brackets – for instance, if they are commenting on the administrative structures in their state.

5.1.3 Interview methodology

Interviews only commenced once the preliminary review of Australian reviews had been completed. This ensured that the interviewer had an in-depth understanding of the source material that formed the basis of discussions.

Sixteen in-depth interviews were conducted during June and July 2012, with 19 participants. Questions were asked using the topic guide (see Attachment 1). As the interviews were semi-structured, additional 'dig deeper' questions were also asked that related to these topic areas and to the particular area of expertise of the person being interviewed. These were asked in order to explore something the interviewee had said, or to delve deeper into aspects that preliminary research or end-users committee advice indicated more targeted research was needed.

The category 'warm up questions' included questions about the interviewee's current role, experience and how they were involved in the 2010–11 flood events. As part of this, one question asked was interviewee observations about what worked well or didn't work well during recent flood events. Responses to this question have been included in the analysis. Sometimes interviewees offered ideas that were later 'tested' by presenting the view or observation to subsequent interviewees to obtain a second opinion. One further point to be made is that topic guide questions were occasionally answered by the interviewee prior to their being formally asked. Where this was the case, the topic was not raised a second time.

Interviews were taped with the consent of interviewees, and transcribed using a professional transcription service. This ensured interview recording was accurate and complete. All transcripts were checked against the original recordings. Recordings and transcripts are subject to privacy provisions under the *Privacy Act 1988* and the National Statement on Ethical Conduct in Research Involving Humans (2007).

5.1.4 Interview analysis

Interview analysis was largely qualitative rather than quantitative, due to the small sample size, which resulted in only three interviews per main category. The topic guide questions were used as a framework for analysis, and comments in the transcripts were classified according to topic area. These were then subdivided into comments relating to specific measures or themes.

In terms of structure, comments were ordered as logically as possible – for example, in the order 'prevention–preparation–response–recovery'. Sometimes, where measures that are not common practice in Australia were being explored, the problem the measure addressed was explored first, then the concepts behind the measure, and then the

implementation aspects. For this reason, many of the comments transcribed in these sections are long, but this was deemed necessary as they are concepts that are less well understood in the context of flood management.

Similar views that were expressed by different interviewees were generally included in the tables despite their overlap so that an assessment of the degree of consensus or disagreement could be made. Where more than one interviewee is listed against a comment, this indicates that the idea was expressed by more than one interviewee, with wording primarily originating from the first listed interviewee. This was used primarily when concepts were being explained (as opposed to opinions), or where the interview was with a group and more than one interviewee contributed to the discussion.

Words in inverted comments are quotes. However, often the spoken word was not concise, or comments required specialist knowledge of technical terms. In these cases, the wording of the interviewee was followed as closely as possible, but was slightly modified or abbreviated. These were not placed in inverted commas.

As an example of how wording was modified, one original comment was:

> 'Well things that worked well in terms of immediate intervention was to be able to get some resources out to, in our case, the regional natural resource management bodies, to be able to support the engagement of volunteers in the clean-up work. One of the things we did was to make some funds available basically in advance, available of a couple of hundred thousand dollars to each of the two regional – regions that were affected. So that they could support their engagement of the volunteers to get out in teams to help with the clean-up of the waterways and other affected areas.'

In the table, this was abbreviated to:

> In terms of immediate intervention, we were able to make some funds available in advance, a couple of hundred thousand dollars to each of the two regions that were affected, so that [regional natural resource management bodies] could support the engagement of volunteers to get out in teams to help with the clean-up of the waterways and other affected areas.

5.2 Warm-up questions

1. Do you have a couple of examples from the 2010–11 floods of things:

1a) that worked well

Code	What worked well (management)
LG#1	(**on preparation**) 'We already had a flood management plan in our council … so we already had pre-determined actions … we meet twice a year where the flood wardens bring in their concerns and that's how we tap into the local knowledge'; 'It seemed silly that we were even meeting in an era of extreme drought but however we continued to meet and we all said to each other that it'll rain one day.' 'There's a number of lakes through our municipality. We utilise them in the irrigation network. So we have the ability to draw down some of those lakes to make room … the water takes a while to get here so we've got time to put some preventative measures in place.'

EM#2 (QLD)	(**on emergency response and systems**) 'We have a robust disaster management system under the *Disaster Management Act* … In terms of the way in which our planning disaster system worked and responded, I think it worked and responded very well.'; 'Our coordination mechanisms worked very well. Our cross government collaboration worked very well, to mobilise all Queensland government to access resources, to provide the assistance where we could on the ground … it's a very coordinated system. So we haven't had the problems of other jurisdictions in terms of lack of whole of government coordination, lack of leadership in relation to the floods. Another thing that worked well from the perspective of Premier and Cabinet was the political leadership we had during the floods with Premier Bligh at the time … Our communication strategies with the public worked well with a range of communication techniques used.'
EM#3 (VIC)	'Examples that worked well were not state-led at all …We've had some really good instances of communities coming together to form networks and groups and actually getting back on top of things.'
UT#1	'In a large flood event one of the biggest problems there is that the duration of the event and the scale of the events mean that any – I don't think there's any water company that wouldn't be overwhelmed in a large-scale event. Because they've been shrunk to the smallest possible size to be efficient and cost-effective and be lean and mean. Which means none of them hold the capacity to respond to large-scale events or for events that extend over long durations of time … so the only way to survive is now through mutual aid arrangements. So that's really a positive thing that we've done that. That's not just deploying resources, also deploying expertise.'
LG#1	(**on communication strategies during the flood event**) 'In the initial stages, various agencies were having their own [community meetings] … the community [was] meetinged-out. Once we organised that no one was having a community meeting until X, Y, Z had been informed and who would be actually running it and be the control authority, that was better … we were getting clear messages out there to the community.' 'In the previous events we kept media on the outside and they started to print information they got off Facebook – they've got deadlines.' For the 2010/11 floods, 'we actually brought the media into our meetings … they sat through the debriefs … then we would have a discussion with them after, 'this is what you can and can't talk about'. That was so much better and the media were fantastic once we'd established those protocols and those lines of communication were getting good information out there.' The CMA representative landed by helicopter 'and when she spoke to the crowd they were angry. When the local flood warden got up and spoke to the crowd, because he was a local identity, a local face, he just calmed the crowd quickly … there was an element of trust. That's important in these communities.' 'There were some errors in the text messaging that went out … we asked for them to be screened by the MECC, the municipal emergency coordination centre, for correctness … it's just getting that locality right … reviewing the intelligence before it went out and also predicting what areas were going to be impacted.'
EM#1 (VIC)	'Information and intelligence provision worked well … we had a fairly good set-up for command and control in terms of the span of control that we set up for each one of our instant control centres.'
FM#1	(**on helping communities in the recovery phase**) 'Things that work are endless face-to-face communications with individuals and little groups of people where they can just continually unload. Sometimes that gets quite

	heated towards authorities but at the same time it's a necessary process to go through in order to be able to pick up the bits and start working in a positive way … treat people with cotton wool a little bit after floods and work very closely with them.'
FM#1	Often the community is made up of some leaders and a whole lot of followers … sometimes leaders may use the opportunity to soapbox a little … some leaders may take the opportunity to show real heroic-type leadership … it's very important to be able to separate the two … empower those ones who often come from left field and put their hand up and behave really well.
ER#1	In terms of immediate intervention, we were able to make some funds available in advance, a couple of hundred thousand dollars to each of the two regions that were affected, so that [regional natural resource management bodies] could support the engagement of volunteers to get out in teams to help with the clean-up of the waterways and other affected areas.
INS#1	(**on insurance and recovery**) 'Depending on which area in Queensland you're in there was a greater penetration of flood insurance in the community. So rurally about 90% of people had purchased flood cover; in the city of Brisbane and Ipswich only about 85% of people had, and in the Lockyer Valley it was treated as a different type of event by insurers, so 100% of people had the appropriate cover for that event … that's sort of the context of how well those communities have been equipped to recover.' 'Over 100,000 claims when you combine it with the cyclone event that happened at the same time … 85% of people in the city, 91% of people rurally – got a payout and got assistance quite quickly, certainly within about 21 days rurally and about 28 days in the city. So people were able to move on very quickly.'
ER#2	'[in] the suburbs where [reconstruction is] happening more autonomously, I think there people are making changes knowing that there that is potential risk in the future, perhaps an increasing risk … houses near Graceville and Oxley … there are a lot of houses that are raised up quite high, literally. It's very impressive … and then not building in downstairs again – leaving those areas open.'
	What worked well (positive effects of the flood on natural resources)
ER#3	Research during flooding into the movement of fish between rivers and floodplains and study of their diet and reproductive tissues highlights the importance of the connection between rivers and floodplains for fish recruitment and productivity: 'most of the productivity in these river systems is driven by floodplain interaction'.
FM#3	'Our variability of flows and the variability of our hydrology means that we don't have enough water. Well in fact, we have lots of water. It just comes episodically, and our system is designed to store it, and our lakes – natural systems – are designed to, if you like, capitalise on it. These floods – it's not just that they've given a bit of a flush to a couple of birds - they've actually reset water security for the next decade.'
FM#3	In terms of the environment the floods have been fantastic. There are arguments about top dressing your fields and things like that. That's true to an extent but it's not as powerful as in, say, North America and Europe where you've got much higher sediment loads. In lowland [aquifers] you certainly would be replenishing ground water. I'm just not sure of the balance from these giant floods versus normal regular ones.'
FM#1	'from an agricultural perspective, not everybody loses. Climate change can create wetter areas and drier areas. So some landscapes actually can potentially be improved through it and…some farming systems can potentially be improved by the odd flood, both in terms of dropping nutrients and wetting up the profile and washing away salt.'
ER#2	'from all the data that I'm aware of, the most amazing recovery is in the waterbird

	data...the Eastern Aerial Waterbird Survey, which has been going for 25 years or something, it's [been] showing that incredible decline, very depressing. I think that their numbers have increased, perhaps beyond even this other new survey now, after these two good years.'

1b) that didn't work well

Code	What didn't work well
EM#2	(**on prevention**) 'There were quite a lot of new properties that were submerged and so that probably raises questions about local government planning. How did brand new properties have just their television aerial sticking above the roof? ... There's been minimal complaints about the actual disaster management system itself. The complaints seem to be around how better could the mitigation system be.'
EM#2 (QLD)	(**on preparation**) 'Some of the local government plans probably weren't as robust as they needed to be in the local disaster management area'; 'You could say some of them were very small authorities so they might not have had the resources they needed to prepare for the scale of the disaster. But one of them was a large authority'; 'We had Cyclone Yasi at the same time … Cairns City Council, in terms of its evacuation centres, for some strange reason chose a glass building as their evacuation centre.'
FM#2 (QLD)	'From a community point of view, absent was property-level information about the extent of flood risk.'
LG#2	'If [the town] was inundated, SES would make the call to shut power off. When that occurred, obviously we needed to be advised. There was no preparation or discussion with us … to advise us of the best approach, how much time do we need?'
LG#1	(**on preparation and warning systems**) What tends to happen is the water breaks out [of the main river channel] and then enters these anabranches which are typically dry streams. You've got gauges and the telemetry system on the river itself but anabranches are unmonitored, they don't have any warning device … What happened at that [river] gauge was it actually flattened … So we lost probably about four or five hours in preparation.
EM#3 (VIC)	(**on response**) 'some of the issues around … the extent to which the state can sustain management capacity when we have large scale or a very rapid onset type incident'
EM#1 (VIC)	'things that didn't go so well… maybe resourcing in terms of some of our resourcing models…they seemed to work archaically slowly at some points in time'
EM#1	'I don't think our evacuation planning was up to speed at any time during the event…that's got to do with the current emergency meetings and arrangements and the agency that's responsible for doing that, not necessarily thinking evacuation planning is important'
LG#2 (NSW)	A lot of the issues we did have were during the evacuation time… [the communication style] 'brought a bit of a panic situation for a lot of people and it flooded our phone networks…so communication broke in that part…we were operating on mobile phones at the time and we couldn't get through…that was a big issue.'
EM#3	…a bit of a fallout from the Black Saturday response effort, that the government will be seen to actually come in and help them…but we had two different parties in – the Labor party for the fires and a Liberal for the flood. So very different policies – and there was the loss of 173 lives in the fires…it did create that expectation and there was quite a lot of noise from the community about the difference between the responses.'
LG#2	(**on recovery issues**) 'roads, for instance, having material to redevelop these roads. We have struggled.

	There's not enough quarries, there's restrictions on buyers of quarries, licensing of quarries and new cuts, things like that. That's a very large problem for us at the moment, that we can't build infrastructure … transport is the largest cost of any job or work that we actually do…levees require a class A type of clay material to develop them…you've got to transport it so it's a very, very expensive exercise…after a flood the areas of borrow pits and things like that, they're inundated with water so you can't get to them immediately when you need them.'
LG#1 (VIC)	'it's very flat and we've only got a one metre in 18km fall…it spreads vastly …so the water stayed in our area'
LG#3.2 (QLD)	'It took us six months to get those Community Development Officers on up here in Queensland. It was a real struggle. It was an opportunity lost. It meant that they spent a lot of their time catching up rather than pushing forward. Whereas in Victoria, which was much smaller in terms of scale and impact….they had CDOs on the ground six days after those events.'
EM#3 (VIC)	'some of the recovery programs are still running from the 2009 bushfires, whereas recovery programs from the flood event have just wound up.'
LG#3.2	'The physical scar, six, twelve months later is still there, but by and large you can drive into some of those places and shrug your shoulders and go 'well what could have possibly happened here?' There's virtually nothing on the surface that's still evident. You start talking to people…there's a lot of those places and understanding how that broader community psychology is actually standing up: a lot of those places are really on the edge of just needing something else to push them back into almost a dysfunctional way of thinking…Symbolic activities that showed how strong we were and how we were working together and we'd all support each other, you get a bit sick of that after two or three months and so people are then left to deal with a lot of this pain and distress and their own personal losses themselves'
EM#3	'Unlike fire, flood doesn't leave that scar…it's not until you actually walk up to the front door and take a peek inside that you actually get an idea of the impact to the household itself. As in the people and the building.'; 'There's a whole ripple effect – it's a bit like an onion. Once you start peeling layers off you can have this increase in family violence and more depression and psychological issues that come about across the whole community.'
INS#1	'Fifty per cent [of those without flood insurance] didn't have the right information, and that we see as one of the biggest issues impacting communities' ability to structure themselves properly financially to recover from disaster because quite a few of them seem to not understand that they have those risks in the community'
ER#2	'I'm not sure in the public areas, which is probably where planned adaptation should be happening, if there has been much change at all that will make it more robust.'
ER#3	'In a number of areas [people] went in and straightened channels, removed all the riparian debris and riparian vegetation and effectively made the channels much more transmissive. So they basically ... increase the stream power within the channel.'
UT#1	(**on financial impacts**) 'All levels of government are finding that disaster costs are an excessive burden. Which is probably their own fault because they've gone through 20 years of claiming the government will do everything for you.'
EM#3	'They were faced with a house that had been completely inundated by floodwater over the flood that their insurance company didn't cover, and very minimal grant assistance was available from the government … they had to replace entire houses of floors and plaster … some of these areas [are] very low socio-economic communities. They just couldn't afford it.'; 'We have households that simply can't afford insurance … it's just not the highest priority in a very tight budget.'

EM#2	**(on Wivenhoe Dam)** 'There's civil litigation. Interestingly, the plaintiffs are bringing their experts from the United States. They're not using any Australian-based experts. United States is obviously a country … where people are hired and paid to give expert testimony. You're talking about billions of dollars in litigation against the government over the operations of the dam.'
	What didn't work well (negative effects of the flood on natural resources)
ER#1.1 FM#3	(**on erosion of farmland**) 'There were some areas where, for instance, the Lockyer River had overtopped a point of land which was a beetroot farm, and probably cleaned about between 30 and 45 cm of topsoil off. It was about a 40 acre paddock, which would have been a lot of loose sediment lost. In that same block there were quite a number of substantial gully erosion features as a direct result. So there was quite a lot of scouring of waterways by the event, but also some of this slumping where the land was wet.' (ER#1.1); 'massive erosion and damage and loss of land in these June floods … a lot of scour on floodplains. Loss of fences is a major one.' (FM#3)
ER#3	John Olley has just completed the estimates for how much sediment was lost from the mid-Brisbane reach in that last flood. It was an enormous quantity … as the floodwater went out over the riverbank when it was draining back off, because there are no vegetative banks in that region there were mass failures all the way along. It wouldn't have taken much from those landowners to have prevented that from happening.
ER#3 ER#2	(**on black water**) The view is that because the flooding regime has changed dramatically since European settlement, flood events don't occur with the same frequency that they used to and so people are experiencing black water events. Water goes out into vast floodplain forests where there's a lot of accumulated organic material. The dissolved organic material decomposes and then consumes all the oxygen. There are water quality consequences from that and it results in huge fish kills.
FM#3	(**on salinity**) 'The sort of big floods we had down the bottom end, you're going to get a lot of water going in, we're going to have salinity back on the agenda now with groundwater starting coming back up again in the lower aquifers.'
ER#2	(**on recovery of ecological communities**) 'The anecdotal evidence and accepted wisdom is that these big floods drive the booms in the ecological functioning and that while during the droughts some of these [ecological] communities might be suffering and declining in condition as we judge it, but then these big floods will come along and you'll get a boom of different processes that regenerate the community. So we went out to the northern Murray-Darling basin area in the cotton-growing areas (that's where the funding came from, the Cotton CRC), to look at improvements in conditions and recruitment of those floodplain key species … We were very disappointed to find very little. No red gum recruitment. So I guess the conclusions we draw from that is that it's much more complicated than just needing water and perhaps surviving … the need for long-term monitoring.'

5.3 Questions on flood inquiries

2. Which of the recent flood inquiries are you familiar with?

Interviewees were asked about their familiarity with the following reviews:

- Brisbane City Councils Flood Response Review Board report (May 2011) (Brisbane Review)
- Queensland Floods Commission of Inquiry (interim report August 2011; final report March 2012) (Queensland Inquiry)

- Victorian Review of the 2010-11 Flood Warnings and Response (interim report June 2011; final report December 2011) (Victorian Review)
- Natural Disaster Insurance Review Inquiry into flood insurance and related matters, (Trowbridge, September 2011) (NDIR)

Some interviewees mentioned other Australian reviews with which they were familiar. As interviewees were not specifically asked about other processes with which they were familiar, their inclusion in Table 2.1 is indicative only. Reviews mentioned include:

- Parliament of Victoria's Environment and Natural Resources Committee Inquiry into Flood Mitigation Infrastructure in Victoria (29 August 2012) (ENRC Review)
- Review of the Bureau of Meteorology's capacity to respond to future extreme weather and natural disaster events and to provide seasonal forecasting services (Munroe, December 2011) (BoM Review)
- Reforming Flood Insurance: A Proposal to Improve Availability and Transparency, Consultation Paper (Treasury November 2011) (Insurance: Treasury)
- Reforming Flood Insurance: Clearing the Waters, Consultation Paper (Treasury April 2011) *(Insurance: Treasury)*
- Review of Recent Australian Disaster Inquiries (Monash University, October 2011) (Monash Review)

A familiarity with overseas reviews/approaches to flood or floodplain management was noted during four interviews. Countries included the United States, Scotland, Canada, the Netherlands and China. This was particularly the case for those involved in research.

Table 2.1: Reviews with which interviewees were familiar

Review	Interviewees
Victorian Review	(FM#1); FM#3; LG#1; EM#1; (EM#2); EM#3; FM#2; (LG#2); LG#3.1; LG#3.2; EM#2; ER#3
Queensland Inquiry	
Brisbane Review	(LG#3.2); INS#2
NDIR	EM#2; INS#3; INS#2; INS#1
	EM#1
BoM Review	
Monash Review	UT#1
ENRC Review*	FM#3
	INS#1
Insurance (Treasury)	

* The ENRC Inquiry had not been published at the time interviews were conducted but one interviewee was following it through the submissions process.

Some interviewees indicated that they had only slight familiarity with a review. This was the case for those identified in brackets.

As might be expected, people had greatest knowledge about the reviews produced in their own state. Thus lessons learnt may have limited ability to cross state boundaries. This was the case for all categories except insurance participants, where companies have a national coverage.

Four ecosystem research interviewees (two interviews) said they had no familiarity with reviews, which could indicate a degree of separation between the review processes and ecosystem approaches to flood management. The remaining ecosystem research interviewee autonomously engaged with the review process in their state, having observed post-disaster activities they thought would greatly increase future flood risk.

Table 2.2: Interviewee place of residence

State	Interviewees
Victoria	FM#1; FM#3; LG#1; EM#1; EM#3
Queensland	FM#2; LG#3.1; LG#3.2; EM#2; ER#1.1; ER#1.2; ER#1.3; ER#2; ER#3 LG#2; UT#1; INS#1; INS#2; INS#3
NSW	

3. What are your views on the outcomes of flood inquiries, above and beyond that which is evident in the written reviews, including:

3a) which key inquiry findings and lessons need to be reinforced and why

Code	Inquiry findings and lessons that need to be reinforced
FM#3	(**on prevention**) 'Certainly the planning ones … planning was mentioned in passing. They definitely have to be reinforced … to me that's the most important thing.' (referring to the Comrie Report)
FM#2 (QLD)	'I think that deficiencies in the planning system are probably reasonably well identified. The problem I think is that there's been a tradition in state governments in Queensland to very much leave land use planning decision-making to local government … I don't think any State Planning Policies have been effectively implemented … policy's not enforced. No planning schemes are being rejected for non-compliance with the old state planning policy.'
EM#2 (QLD)	'Certainly the work in relation to flood mapping and modelling and the work in relation to the planning, and town planning … essentially the mitigation, preventative measures.'
INS#1	'All of the recommendations about mitigation programs and land use programs, land use programs, building codes are all strongly supported by the industry … information about where are the priority areas for mitigation or what are more appropriate land use planning regimes around this hazard so that those future properties will be able to be insured. Probably it's the key issue for us, combined with mitigations for those existing problems that are out there.'
EM#1	'Where the Queensland Report has been quite useful, especially its final report, is where it focused on floodplain risk aspects and really looking at prevention and preparedness. It is probably more important than your response operation in the first place.'
INS#2	'For the insurance industry, and also I think for Australia generally speaking, I think the key thing is the mapping issue – the risk assessments. I think they are absolutely essential to every other component of dealing with natural disaster, the floods in particular. Unless we understand the risk, we can't really properly mitigate or prevent or adapt and I think the fact that both the Victorian and Queensland reviews, and also the NDIR, pointed out the somewhat dire state of mapping in Australia, is pretty important.'
ER#3	'To my mind the key things that stand out in them – and this is where there really does need to be some soul searching – is what local and state government processes led to the extent of development in the wrong place. It seems to me that even though there should have been mechanisms in place to prevent developments in vulnerable areas, a lot of it has occurred – a lot of approvals have occurred.'
EM#1	(**on flood warning**) 'The flood warning ones I think are very important when we're talking about the Victoria Flood Review. The first 30 recommendations there that relate to flood warning are very important, and community education for the SES.'
UT#1	(**on emergency management arrangements**) 'All of them raise issues around creating cohesive, multi-agency responses. That comes to things around collaboration and coordination and cooperation and how information becomes communicated between all those to make that happen … that's really the key

	to high level success – is how you get that one team, all in one approach.'
LG#1 (VIC)	'There needs to be a greater role and resourcing around the SES and their ability to take that lead. In our case our council stepped up because the ICC were overwhelmed. Particularly for a long event … they were totally overwhelmed. So I think as far as the new command and control structure they're discussing … that will be a benefit.'
EM#3	(**on resilience**) 'It certainly gave some context around considering Community Resilience Committees … it was one of the recommendations that's currently not being supported by the state of Victoria … I think that it's a great recommendation.'
INS#2	'I think it kind of came out of the inquiries, pretty clearly, that that type of strategic, comprehensive approach to disaster resilience does not exist in Australia.'
INS#2	(**on expectations placed on local government**) 'Local governments being perhaps a bit over-burdened. That was one of the things I thought that came out of the Queensland and Victoria reviews.'

3b) were there any important lessons or outcomes not covered by the inquiries

Code	Lessons or outcomes not covered by the inquiries
FM#3	(**on prevention**) The Comrie Review didn't sufficiently cover development planning. 'That's a fundamental failing, in my view … it was not through the want of suggesting that's the case. I mean, the view of anybody who works seriously on floods is that prevention [is] fundamentally what it's about'; 'the SES having to wade and save people is just a sign of planning failure'; 'The people setting up these inquiries … don't know anything about planning.'
EM#1	Most of the inquiries of late have been very much focused on a particular event as opposed to necessarily some of the systems which may have led to a success or failure, which might be an issue of more preparedness and prevention measures for the years ahead.
INS#1	'I think overall the issue of mitigation has been touched upon by most inquiries, but none of them has dealt with it comprehensively and none have led on to the more difficult conversation about "how do we fix the mitigation program in Australia". I think that's a piece of work which still needs to be done, a top-down review of federal, state and local government process for actually achieving or implementing a piece of mitigation. At the moment federally they have a bit less than $30 million a year to spend on that; you really can't even build one levee for that.'
FM#3	(**on flood energy and damage**) 'The flood story is always about flood level and flood duration … what's often missing is the effect of flood energy … most of the floods were very low energy but long duration in Victoria, so the water just sits around. But there were also high-energy ones. Most of the cost comes from the energy – you get erosion, you get bridges knocked over, you get roads scoured out. All that stuff is about energy, but it's just not thought about very sensibly. All we care about is how high did the flood get … into houses.'
FM#2	(**on betterment**) 'The other area that I didn't see much attention … the biggest cost was in infrastructure for roads. One of the issues is that … given that's the highest cost – compared to houses it's just miles ahead in cost – are we building roads that are capable of withstanding events that they're going to be subject to? … There is no betterment provision.'
INS#2	'I don't think there was much – a clear enough focus on reconstruction as a bigger task and, when you're reconstructing after an event, how you can spend the money that we're spending on reconstruction in a way that will ensure resilience … the betterment stuff.'

FM#2	(**on handling of the Wivenhoe Dam issue**) [Wivenhoe Dam had] a dramatic mitigating effect … I think they made something like 10 centimetres difference by running models that optimised the release pattern with retrospective knowledge … [the dam managers] were vilified. It was a disgrace … if there was a failure of the Commission it was the failure to actually bed down that issue … part of the problem was that they had lawyers rather than engineers trying to find the truth … not to come to a conclusion on that question was a failure to deliver on their terms of reference in my view.'
LG#3.2	'Dam management took up an inordinate period of the inquiry's time … the opportunity lost was that they then didn't spend enough time looking at system structures, arrangements and making some really telling recommendations around those.'
ER#3	(**on climate change**) 'I'm not seeing any modelling presented in any of that which says that what was a 1 in 50 year event is now going to be a 1 in 20 year event. I think that that that's a really serious omission that these things are likely to become more frequent according to the climate modelling … I think there's a perception that we need to be resilient for any climate variability but if this is going to occur more often and with more intensity then I didn't see that coming out very strongly at all.'
FM#2	(**on flood-related disasters: Cyclone Yasi**) 'I think the cyclone was missed a bit compared to the flood … the extent to which emergency management systems and evacuation centres could have dealt with a direct hit [by a cyclone] … I'm not certain there was any assessment as to whether the evacuation facilities would have been adequate in the circumstances … that wasn't covered by the [Queensland] Inquiry.'
EM#1 (VIC)	(**on evacuation**) 'The narrowing of the aspects of the review around evacuation was not necessarily helpful – the way it was narrowed around vulnerable people and institutions. I think it would have been good if that had been broadened out … Municipal evacuation plans have got to be tailored to individual communities: where's the evacuation routes, how long is it going take, what are the trigger points, where are they going to be evacuated to, what are the trigger points for letting them come back into town, all those sort of things.'
FM#3	(**on benefits of the floods**) 'The perception of these floods is as disasters and "wouldn't it have been better if they'd never happened" and so forth. The reality is they transform all sorts of things. Not just environmental things, which of course were brought back from the brink, but also social systems. If you look at the amount of water that's now available, that water's worth more than the land in most places. So it's basically saved whole industries and whole communities and yet there's this sort of perception of these evil floods coming down … in fact if you did a cost-benefit analysis on it there'd be way more beneficial than detrimental. But inquiries never look at it in those terms, or never ask, "Well, floods are going to happen. How can we manage them so that there's the best [outcome]?" Especially western Victoria, those towns without rivers and without water were basically doomed. It's actually saved whole communities … basically all the lakes in the state apart from the coastal ones were dry … these floods were big enough to actually fill these lakes … the same with our big reservoirs. This is the other thing no one mentions. All our big reservoirs are carryover storages. So they've got [capacity to hold] five or six times the annual yield. The only way to fill them is with big floods. There hadn't been any big floods really through most of Victoria since '74, '75, a bit in '81 … the whole water system only works by having the carryover storage in there. The only way to get that is to get more water in a year than on average. So you want a big flood. The way the whole system works, both Melbourne and irrigation, is fill up your dams in

	big floods – and they've got to be whoppers – and then you just keep surviving off that water for the next decade.'
FM#2	(**on the Queensland Inquiry: inquiry style**) 'Well, this was a very legalistic review in some ways. That may have given rise to some reasonably simplistic recommendations, say in relation to levee banks. "The Government should regulate levee banks" – that's not very helpful.'
LG#1	(**on volunteer management**) 'I don't think that was adequately addressed in the [Comrie] report, actually, how they do volunteer management. Volunteers that turn up totally under resourced. Then they turn around and say, "Oh by the way, can you feed me?" So they become a burden. I did have people ring up and say "I've got 20 people wanting to fill sandbags, can you send me down some sandbags?" "Where are you going to take them?" "Oh, I don't know, I need sandbags and sand to put in them." "But what are you going to do with them?" "Um, well …" Volunteer management was not addressed adequately in the review either. 'Someone might be willing to come in and use their excavator to do a particular job for a couple of hours if the event's only going to be for a day or so, but when you've got a long protracted event that lasts for almost four weeks and then in comes an account at the end of that four week period … if someone comes in to help out … "Are you coming as a contractor or as a volunteer?" so that you don't get any surprises down the track when people start putting in claims.'
UT#1	(**on human nature and the limitations of review processes**) 'One of the problems in the reviews is that you can highlight technical things that need fixing … But the complex ones are the cultural issues they raised about if people don't work together effectively. All these are actually driven by cultural issues about people's attitudes in between organisations and egos and they're all very hard things to solve.'
INS#2	(**on relief funding**) '[The Government] ended up paying out over $800 million in $1000 payments, which might have been useful for people if they lost electricity and their fridge full of food. But in the long run – people whose houses were destroyed, it didn't offer much comfort, $1000 … it was pretty poorly targeted.'
ER#3	(**on recovery activities**) 'A lot of the focus, quite rightly, of those reviews was on the risk to property and risk to life … quite a number of people died … because of the sensitivity of that issue, there was no careful discussion about what might be some of the externalities, of not only what the floods did but … of the perverse outcomes of the response to that … That's one of the things that … didn't come out as strongly, that you've got to be careful that your mitigation – your adaptation response to flooding – doesn't have perverse outcomes in other sectors. I don't think the externalities were that well considered, particularly for downstream.
EM#2	**(on insurance)** 'The concept that you put an insurance pool in place, anything over that what the market could sustain and the monies would come out of the insurance pool, that's probably another situation of the government coming in and regulating the market and I don't know if we've got such a market failure that the government needs to regulate the market. So that case wasn't necessarily made in the insurance review … I don't think anyone looked at market intervention or regulation.'
INS#3	'The analysis of a lot of the reports [doesn't] necessarily understand the cross-subsidy side of things.'

5.4 Questions on efficacy of different measures for climate change adaptation and priorities

4. Do you have any opinions on how Australia should to adapt to a climate change scenario that predicts floods of changing frequency or magnitude:

Question 4 targeted climate change adaptation. However, it should be noted that this often led to discussions about which measures would be most beneficial to tackle floods in general. Discussions about future flooding threats were not only confined to climate change, but also to other future scenarios such as demographic changes.

A handful of interviewees also had reservations about climate change – not so much the effect of it on flooding but the relative significance compared with other factors. This inevitably affected the emphasis of discussions. Thus comments in response to Question 4(a) have been categorised into different measures people felt would be most effective to tackle flooding in general, whether or not the interviewee was specifically addressing climate change adaptation. Attitudes to climate change have been analysed, and one category also addresses approaches to climate change uncertainty.

The analysis of comments in response to Question 4 is found at the end of the document (under the heading 'Analysis') rather than being analysed at the end of each sub-section.

5.4.1 Understanding of climate change impacts on flooding by interviewees

All interviewees were asked about their understanding of the anticipated effects of climate change on flooding. Climate change impacts that were identified in interviews are listed below. The number in brackets indicates the number of interviews (out of 16) where the climate change impact was identified:

- increased flood intensity (14)
- increased flood frequency (9)
- increased drought (this was commonly identified as something that would also exacerbate flood risk) (8)
- sea level rise (7)
- greater flood risk in estuarine environments due to interactions between sea level rise and increased rainfall (3)
- more flash floods (2)
- cyclones further south (2)
- median flood risk decline (1)
- increasing problems with sulphidic sediments in inland waterways (1)
- increasing climate variability (1)
- more energy in floods (1)
- increased storm surge (1).

All interviews demonstrated a good understanding of the impacts of climate change on flooding except for two interviews which did not answer this question (INS#1 and INS#3). When responding to the question, these interviewees pointed to natural climatic variability and short timeframes for setting insurance premiums as negating the relevance of climate change.

Some selected comments relating to climate change impacts are as follows:

FM#3	'The dry times are just as important to flooding as the wet time. Then you're going to have more intense extreme events when they happen. That's a major shift in vegetation which can have carryover effects – second order effects on erosion and sedimentation.'
ER#2	'Traditionally people thought there were no sulphidic sediments in our inland waterways. But because of river regulations and increasing salinity, sulphidic sediments have built

	up and accumulated in areas that have been more permanently flooded, so places where there are weirs and things like that. When you get a drought – so this is going to increase in regulated areas with climate change – those sulphidic sediments become exposed and acidified. Then when you get a flood following that, there's a huge potential to wash that acidified water or sediments and practically poison vast areas of wetlands, which has happened. So there are lots of water quality responses after these great big floods. '[Floods would wash the problem away or dilute it] if you [regularly] had your small and your medium-sized floods happening, which is what has been removed by river regulation. That pattern will be exacerbated by the projected climate changes … [if you have] lower mean flows and then big, slushy floods – you've got much more chance for accumulation of all kinds of what we think of as degrading processes during the dry period. Then these big floods [act] as agents to disperse invasives that have been doing quite nicely during the dry periods; to cause black-water events; and to shift sulphidic sediments and poor water quality. So I think there's a lot of risk actually associated with those individual events in the future, given a context of overall drying. 'There's a much greater risk if those big floods happen after a period of dry, much the same as bushfires could be a lot worse if there's a dry season following a period of good rainfall because you've got more fuel.'
ER#3	'As the hydrology becomes more intermittent, the river channels are going to change. They're going to be naturally want to be more vegetated for longer periods. So it's actually understanding how the channels will behave when they're like that otherwise we're going to end up with just concrete everywhere. Even with concrete, all they're going to do is pump the problem downstream and cause some really major, major problems.'

5.4.2 Attitudes to climate change

Attitudes to climate change varied. While none disputed the evidence of climate change or its effects on flooding, opinions differed about its relative significance to future flooding and how it should be managed. The difficulty of incorporating it into development planning was the greatest issue. A range of views are reproduced in the following table:

INS#1	'Insurers in general are not particularly focused on climate change as an issue, because we're insuring in sort of the one to five year bracket in front of us. So while we will notice we think the risks change over time, that's where our financial skin is … So we're not sitting back and going "We wonder what it will cost to insure a house in 40 years' time based on IPCC or CSIRO predictions?" We're more focused on the here and now, and we've already got a lot of extreme weather exposure in Australia. 'So in a general sense we're interested in climate change adaptation where it will lower the exposure to current extreme weather risks, with a natural extension of that being that if in the future climate change risks exacerbate the extreme weather that we'll already have an adaptive process in place to start dealing with that.'
INS#1	'Insurers have [climate change] as an item on the agenda for consideration if we're asked to comment on how high should the new ring levee at Maitland be, so we want to see those factors built in for that long-lasting infrastructure. But 90 per cent of our focus is on 'get rid of the problem that we've got now, please', rather than putting in 100 per cent of our time arguing about what it might be like in 100 years' time. So I guess we just need that slightly more intermediate focus from our perspective on adaptation to

	weather rather than climate.'
INS#2	'How can we minimise the impacts of these types of events in the future? If you are going to do that properly, you need to assess – as I said before, what is the risk? What are we facing and how can we plan for the next 10, 20 years, at least, in addressing that risk? So if the science is that climate change will have an impact on flooding risk, within the next 10, 20 years, we've got to take that into account in how we deal with planning issues and the mitigation issues.'
INS#2	'For the business, we're actually looking at a wider risk or a longer term risk. But in terms of setting premiums … Although we're only setting it for one year, if we have a customer for 20 years, and in that 20 year space, we know that they're going to be flooded at least once to pretty much partial destruction of their home, we're going to have to try and recoup $100 000 … For overall assessment of the business, about how we need to build premiums, we do have a longer forecast. We only really build in climate change at the moment, I understand … if the council study has incorporated climate change into their flood study … We don't actually get separate information about climate change and then build that into our model.'
INS#3	'I do think that the impact of [climate change] is really small in an annual sense compared to things like La Niña or the El Niño. There are a whole lot of phenomena that Australian weather patterns are impacted by, that are far more impactful on our weather than global warming. So there's things like the Indian Ocean Dipole. There's the Pacific Decadal Oscillation. There's the Southern Annular Mode. All of these climate indices. So you've probably heard of La Niña and El Niño. During La Niña years, it just rains a whole lot more than during El Niño. That signal is a huge signal. So it might rain twice as much in La Niña than in El Niño in any one year. So given that that's going on with its huge impact up and down, then a slight upward signal is almost lost in the noise, you know? So I think it's going to be a long time before we can point out to the impact of … climate change, rather than the annual impact of these four indices all working together. That's huge. It's really – they are huge, huge impact. Climate change may be half a per cent, these things are 100 per cent impact. So it's 200, 300 times more impactful in any one year.'
INS#3	'Insurance is never about the average. It's always about the outlier. So what could happen is – yeah, sea level has gone up … and there's a king tide, and there's a cyclone, and suddenly, places that, in the past, weren't at a risk are suddenly at risk now of storm surge. So once again, I think that is a small, creeping – it's almost like a steamroller. Once it hits you, it hits you, but it slowly creeps up on you. It won't jump at us. And because insurance is an annual premium, we would have time to react if required … I doubt that it leaps forward huge amounts in any one year … I doubt it jumps up a foot in one year, put it that way.' 'Traditionally, insurers … drive by looking out the rear vision mirror. And I think that there's a certain amount of truth in that. So being very fact-based sort of people, if they can't actually see the evidence, they won't really believe it. So taking a call that climate change is going to raise water in 60 years' time, therefore, we increase premiums now – I can't see many insurance companies doing that. Certainly, within the first couple of years, you're going to lose all your market share, because you're going to be really expensive compared to the others that don't have the same beliefs as you.'
UT#1	'I'm not terribly excited about worrying about climate change's effect on flooding when we can't even get people to believe there's been flooding in the past. So if you look at the Brisbane floods, you go back to the first explorers came up the river. They talked about flood debris that was far higher up those trees than anything we saw this year or in '74 or in the 1893 flood. So we haven't come to grips with it with our current flood risk, without even thinking about the future flood risk.'
EM#2	'My message to emergency management people who then said, gee nothing to do with us – it's climate change … they've really got to concentrate on what this is going to

	mean for them in terms of the potential of larger disasters including more frequently.'
EM#1	'I think climate change more broadly in emergency management is an issue that has just gone out of people's visions … it's not necessarily a negative attitude towards it.'
FM#1	'I'm not sure how much the world changes in terms of flood activities, both in terms of response and recovery, given various degrees of climate change impact. I think a flood is a flood and they've been happening since time immemorial and I think it's a very brave [person] to predict the flooding-type patterns will change in any significant way to the extent that it will affect how we might react to them.'
FM#1	'It's important to think about flooding from a climate change perspective but also think about agriculture in general from a climate change perspective and think of it not in the sense [that] it'll all be ruined but the fact that it creates as many opportunities as it closes doors.'
ER#2	'Places like the Netherlands – well all through Europe – [are] actually designing their mitigation measures and their catchment plans using worst-case scenarios from the climate change projections. So we definitely should, given our inherent variability, climate variability.'
ER#2	'[The current] approach is treating things as though they're static. I think that's an opportunity that climate change affords us – start considering things in a bigger spatial and temporal context.'
ER#2	'In my role as network coordinator I tried early on to initiate some event to bring people together from different disciplines to think about water management and measure the freshwater ecosystem with respect to climate change and received a very cold response … the kind of comments went along the lines of, 'Oh, we shouldn't be talking about climate change at all, we should only be considering climate variability' … if you look at warming or any other variables, there's climate variability but climate change on top of that could be quite significant and creeping and changing our variability.'
ER#2	'We should be putting much more resources into the adaptations and what options there are available and particularly how to select options that are actually appropriate for the full range of uncertainty. There are lots of adaptation things that are going to be good under a drier climate or a wetter climate. Also the emphasis should be on how to integrate different values.'

[Heading as per other questions] the types of measures most likely to assist adaptation to less predictable flood events? (Question 4a)

5.4.3 Climate change uncertainty

EM#2	(**uncertainty, planning and policy decisions**) 'Local government people were saying, "Okay, fine, if we're going to make decisions, planning decisions and saying 'no' to planning applications based on climate change science, it needs to be a lot more precise than what it is because we need to be able to say before a court, this is why we're not allowing development. If we said we're not allowing development here because of the potential that climate change will rise sea levels in 50 years' time, the courts are going to overrule it.'"
LG#3.2 LG#3.1	'New South Wales and Queensland have come up with a different sea level rise number … Now part of me just goes, how on earth do you expect all councils … to agree and have some kind of supportive and coordinated attitude to how they're going to deal with climate change impacts and look at adaptive activities for their community if you can't get two states to agree.'; 'Queensland's adopted 80 cm ocean rise by 2100 and New South Wales have gone for 1 metre.'
FM#2	'I think we've got more certainty with temperature rise, less certainty with sea level rise and then less certainty again with rainfall patterns and intensity of rain events … there's a higher level of uncertainty with the impact of climate change on the actual heights of flood events which makes it much more difficult to establish a credible policy intervention.'
FM#3	'Hydrology is based on the past; on the past records. Whereas climate change is all about the future … it's a very difficult problem to know how to do policy based on past records where everyone's uncertain about the future. Well, you can't. So I see that the danger of climate change arguments here is that it undermines very solid, very effective planning. 'Flood planning is all about predicting floods. We have to make predictions of their frequency, their magnitude, their extent. If you base it on the past record, we're actually pretty good at that. In most places now we can predict with, not quite centimetre accuracy, but pretty good, where your 100 year and different events will get to. What the climate change does is it makes that much less certain. One of the consequences of this is that it makes people less confident about the predictions that we already have for flood extent and frequency magnitude … they're saying … "All this flood data you're showing us – we're not confident about any of that anymore … if you're less confident we'll be less conservative" … I've certainly seen that in policy discussion where people say … "Past records don't count anymore. Because the future's much less certain for flooding … okay, well, just let's forget the whole thing." Well, it's a sort of an unintended consequence of uncertainty.' 'You can't say, "Show us the extent of the 100 year fire." It doesn't work. But you can say, "Give us the extent of the 100 year flood" … there's almost no hazard that is as predictable, and the whole climate change thing is giving people an excuse to not take that certainty into account … Nothing plays into the hands of developers like uncertainty … I reckon the response is to say, we should continue to manage with the data that we've got and continue to use that and make decisions on the basis of it. That's all we can do.'
FM#1	(**approaches to address uncertainty**) 'We virtually separated those two things out and said – our view was that there wasn't a hell of a lot we could do about the likelihood … but there was a fair bit we could do about the consequences, and our focus into the future is to try and work out how we

	mitigate against the consequences of flooding and how we make communities more resilient to the reality of them. So we concentrated on a right-hand side of that risk equation, not the likelihood/frequency type one.'
EM#1	(**on downscaling climate change information**) 'One of the things about climate change I think why a lot of people, I suppose, are still sceptics is that the climate change debate has never been able to reach down into somebody's backyard. We find that if we … talk to somebody about their flood risk, we need to be able to talk to them not on a suburb basis or a township basis. On their actually property. So the same thing I think if we're going to talk about the risks that climate change actually, I suppose, poses to people and their properties, we need to be able to say how they're going to affect their individual property … It's almost like somebody needs to get a personalised little fact sheet of all the different, potential impacts that they might face on their property and be able to see that on a map basis.'
EM#1	'Improving the confidence of climate change predictions obviously enables better buy-in from politicians and senior public servants in regard to the approach that is taken to mitigate impacts. I think complete certainty is never expected, but I think more confidence in the debate.'
ER#2	'All the projects I've been involved in recently about downscaling and providing information and climate change projection information just really suggests that it takes a lot of money and [human resources] to do this kind of downscaling and the uncertainties just grow enormously and there's no evidence that that really aids in decision making at all. I'm of the opinion that those resources should be allocated towards identifying management options and prioritising them, knowing that you've got a range of potential changes to your hydrology.'
ER#2	(**on communicating uncertainty**) 'How to communicate the uncertainty … I think novel ways of presenting information through … games – you know there's some about catchment management and water quality that have been really successful on the ABC website. They're doing that kind of thing for climate change scenarios.' [ABC Science Catchment Detox Game: http://www.catchmentdetox.net.au]
EM#1	'I think we could probably be a bit more I suppose specific in terms of our climate change education across not necessarily the emergency management sector but I think the emergency management sector could be a way of getting some of the messages out.'

5.4.4 Flood studies, mapping, modelling and risk assessment

INS#2	'Risk assessments … are absolutely essential to every other component of dealing with natural disaster … It goes towards planning future developments … how we should be dealing with existing developments … I kind of see it as a couple of layers. So you've got the first part is the planning. Then there's the building codes and the building controls. Then you go to the infrastructure mitigation. Then you go to insurance at the very end. Each one of those requires a really good understanding of the risk.'
INS#2	'Particularly in Queensland [there's] this reluctance to provide information about risk because of concerns about house prices and being liable for damages … Local councils in Queensland, mainly, are the main culprits.'
FM#2	What's missing is a digital elevation tool which allows people to apply flood study data to their property. What's missing is the Google Earth type map product where you can dial up a flood or a storm surge or a sea level rise and see the impact on a particular property. That's missing but not expensive. The data exists but it's that going from database to user interface.

INS#2	The flood studies used by the insurance industry are not always publicly released documents. We get information from various places. For flooding, it is mainly the local government studies because they're the ones that do the flood studies. The industry has a National Flood Information Database, built by [the] Insurance Council of Australia and Risk Frontiers. 'It has all the addresses for Australia, or tries to. Against those addresses, wherever there is a flood study or some kind of flood information, it will include the risk relating to that flood information, against that address … at the moment, it's based on, largely, any council studies that are available or any statewide studies that are available. Digital elevation modelling, any information about flood levees and other mitigation infrastructure. It's not very complete. So although it's pretty good in spots, it's not very good in a lot of other spots because there aren't the flood studies available or they haven't been done … The other issue with the NFID, is that the data behind those flood mapping or flood risk assessments is not clear. So we [don't] have that consistent basis and know that they're all based on the same presumptions … [standard flood study criteria] would be very useful.'
INS#3	'Sharing of data, I think, is probably the biggest challenge … people won't want it known, because their property values will come down … councils won't want to do it, because they'll probably put developments in floodplains … the openness of data, I suspect, is going to be a big issue.'
UT#1	'The Australian water sector has developed a model … on working out the impacts of climate change on life-cycle costs. To be able to make better decisions now about investment for the next 40 years.'
UT#1	'We've spent the last three years here at work fighting, trying to get all the flood mapping data for our operating area. We still can't get it. We've got bits and pieces … and we've pieced that together to form our own mapping … in New South Wales I can get access to all the bush fire risk maps for the whole of the state. I can see which areas are going to burn down, which areas aren't. We can't do that for flooding. First you need to be able to know you're at risk, then you need to be trained to understand what that risk means, then you might design it into your asset. But if you don't have the first part of the equation you're never going to get the last part.'
EM#2	'[For better planning] you probably need better maps, better flood mapping … the effect of infrastructure and how that will change the direction of water flow … flood line … depth … if you want to do future mitigation measures then you're probably going to have to have far more sophisticated modelling and that's going to cost quite a lot of money. You could look at it being a federal/state government responsibility to subsidise the cost of developing those models. 'The models themselves are probably more important … in the planning activities in determining what sort of water flow could be expected for certain events, and also the effect of infrastructure … But do you model on every single development application? Suddenly you develop an application and it will take a lot longer and cost a lot more so that's the other thing. So you've got to manage the risk versus the costs associated with undertaking those sort of in-depth studies as well.'
EM#3	What underpins really robust [emergency management] planning is the risk-management process that underpins it and identifying there's a known risk.
EM#1	'[We need to] focus our efforts on looking at the flood risks, identifying how we can manage them better and putting some plans into place to ensure that they are managed in that way.'
LG#3.1	(**on communication of climate change risks**) 'Council are lay people in terms of climate and even disasters …We try to use the analogy of: picture the climate of the place at 600 km north of you now and think about those conditions in your community in 10, 15 years' time.'

LG#1	'I think it needs to come down to a local level. I get the big picture but what does it mean for the people in our area? It needs to be broken down. 'The plan we're currently using, the year 2025 is our sort of gold year. So we've got – some would say it's a short-term view but certainly long-term by the way some people model – but we're looking at what's the shire going to be like by 2025 and we use some of that information to feed into our planning and what we need to put in place to accommodate or to make those things occur. We've got a section in the flood study … It's not very big our area in relation to climate change, we do acknowledge the extremes and a lot of our stuff is being based around 2011 event as being that extreme event. Now that's all based around the 2011 event which is one of those, what I would call a climate change extreme event because it was greater than one in 100 year flood.'
LG#3.1 LG#3.2	(**on incorporating climate change into flood models**) '… some kind of formula that we can apply to our current modelling that will give us a better idea for the planners and those that were looking beyond the interest horizon of disaster management people'; 'The question that was asked was … how much you reckon the rise in runoff will be … in terms of river height as a result of climate change'; '[There was] no resistance or any kind of opposition to it … the concern in relation to it … there was relatively little hard science behind it.'; 'No one had the time nor the money to spend on it being a truly comprehensive – yet even at the end of it just simply by saying look, we reckon you should go plus 10 per cent.'
FM#1	(**on limitations of flood studies**) 'I think [flood studies] a necessary evil and at the end of the day, they've become very big documents that ask a lot of questions and don't necessarily provide a great number of solutions. 'When we first started this thing, we were covered with a plethora of technical studies and flood models and what have you, all of which emphasised our belief that none of those flood studies had come up with anything that was going to work in this situation. So we had to take a fairly radical, different approach. 'A synopsis of all of the previous flood studies … what their strengths were and why they didn't get up … gave us the sense that we weren't going to achieve anything great by going down that track, apart from stalling action. All that would happen is that we'd do another flood study. That would be another 12 months down the track before we had anything to print. We went from the previous studies told us this is what *doesn't* work. We weren't quite as confident about knowing what *needs* to be done. We were very confident about what *didn't need* to be done.'
FM#2	(**on the usefulness of QRA flood maps**) 'St George is a classic little case study where they didn't even have flood mapping and as soon as they did they said, "That was a bad place to put the retirement home, wasn't it?" The QRA did some maps for St George and that really dramatically changed their attitude. Because they basically had up one side of town, which was at a flood risk from water actually backing up. But over the other side of town it looks pretty good so now they know, well we're not going to develop "there", we're going to develop "here".'
FM#2	'SPP 1/03 should provide standardised terms of reference and methodology for … different levels of flood study … we would say that you don't need to have a full hydrological model for St George but we do for Mackay: a reasonable country town versus a growing coastal centre. Where you've got development pressures a flood map is useful because you've got houses going in.'
ER#3	**(on designing models)** 'In highly intermittent systems a lot of vegetation actually grows in the channel … Some of

	the studies that have looked at the effectiveness of "buffers" … the modelling's often done with just a row of trees on the high bank. When you do that it has very little impact on the hydrograph. Actually, that's not the way that those channels are meant to behave.'
ER#1.2	(**importance of looking at geomorphology**) 'The geomorphology [can reveal] some of the historic flooding beyond the records … Because you can look at the sediment course and you can see where the flood extent was in much earlier times. It indicates where the river channel has moved within its banks over time … Where you think a river channel is now, it may actually play with its area quite significantly to an earlier channel which you can't necessarily see without looking at some of the underlying features of the landscape. Then you can use that to assess whether development is located in what is potentially going to be a future river channel once the river moves again. 'The geomorphology work is pretty new and has only so far been done on the Lockyer Valley, so it's a very new tool … Griffith University.'
ER#1.1	'Murphy's Creek, if you look at it from remote sensed images, before that event it was just sort of a meandering little stream. But you look at it now, it's a major sort of carved out waterway, but it's still within the old watercourse. In the "before" images you can see where the old watercourse was. That stream has effectively reclaimed its previous watercourse. So what we need to understand is what will happen in the landscape – because in a big enough event, it may just reclaim a previous watercourse which doesn't have any living memory of having been like that before. 'It also shows some areas where, even in previous flows, it's never been beyond certain points … if you regard it as negative to say, "Look this area is vulnerable", a positive might be to say, "Well this area is probably not very vulnerable."'

5.4.5 Development planning

INS#1	(**on the need to restrict development in floodplains**) 'Appropriate land use planning regimes around this hazard so that those future properties will be able to be insured … probably it's the key issue for us …'
INS#2	'From what I understand from talking to our technical guys, their view is, infrastructure is not the solution. It's about getting people away from areas in the first place. They think that's always the first point that you should be attacking: development controls and dealing with legacy planning issues.'
INS#3	'That's a no-brainer. You shouldn't build on floodplains, full stop. So the new dwellings in floodplains, personally, I'd be against. I'd say, just don't do it. Build on the hill.'
EM#1	'I think we need to look very hard at the way that we look at our future development, especially in coastal areas that are on riverine floodplains full stop. 'Obviously there's greater want by developers, and also politicians to some degree, to develop areas and some of those are on floodplains. We need to be very careful about the way that we do that … There's a large potential to increase the future risk between now and when some of the larger climate change scenarios really take effect.'
EM#2	'There were quite a lot of new properties that were submerged and so that probably raises questions about local government planning.'
UT#1	'One of the things we could do is actually decide to live with floods and actually use our flood plains for food production and low carbon production food because it's close to cities … actually not build on the flood plain. 'I don't believe there's only one driver for the future … I'd say there's population crisis,

	there's actually a global food crisis. There's some sort of big oil crisis coming … just how severe it is, is another story. You start looking at those things, then, if you have a more strategic view you'd be saying, yes, I think we might use these floodplains smarter.'
LG#1	'Some of the lessons, particularly up at the Benjeroop area where the buyback occurred, houses should not have been in that area'; 'if it was me building on the floodplain … (a) I wouldn't build there but (b) I'd put a ring levee around my property.'
LG#2	'Don't build in flood areas. I mean abstinence, you're not going to have an issue.' It's definitely a planning step … obviously identifying potential flooding areas, actually making that information available. Either restricting or identifying for potential purchasing customers that they are within a flood zone and there is a risk.'
FM#1	'We've got the tools to manage future development through local government planning overlays and all the rest of it. There's various LiDAR systems … you can model flooding a hell of a lot better now than you used to be able to. So there's no excuse for new developments being put in vulnerable areas.'
FM#2	'Well I think not allowing new development in risk areas is the most obvious one.'; 'There's no doubt that the planning systems have not adequately managed the risk.'; '[There is] clearly some state interest that needs to be expressed that has not actually been reflected in planning schemes, even with the state planning policies.'; 'I think the state should take a fairly strong role in keeping people away from flood risk.'; 'Goodna – how did anyone ever get an approval to build down there? Rosalie. There are certainly places where there should never have been houses built in Brisbane.'
FM#3	'People are building in dumb places and we really need to do something about it. The first thing you have do to in policy [on] land is to make sure that there are no more houses being built there … Before you clean up the policy messes of the past, of which there are plenty, make sure you're not creating any in the future.'
ER#1.3	'Using the managing, planning and zoning regulations to keep people out of harm's way.'
ER#1.1	'There are some direct things like that, like not putting infrastructure in harm's way … it's also about not putting people in harm's way and … subdividing floodplains for lifestyle blocks is really just asking for trouble. Eventually that country will do what it's always done which is flood. If you're there on a slab-on-ground block you're going to get a wet carpet.'
ER#2	'I think the first thing is to prohibit any difficult-to-revert, difficult-to-remove development in those flood-prone areas. So having a really good agreed-upon strategy for what kind of levels of development are appropriate for the different areas. I think there are dangers in saying, "Oh, let's just wait and see what climate change scenario – how it's going to pan out and we'll just continue and allow development in these areas that we can't pull back from. So there should only be really low levels of development in floodplain areas compared to what's still going on at the moment. I think that's really the priority – is prevention.'
ER#3	'I think the prevention and planning is probably going to be key. So it's going to really require some tough decisions around setbacks [from the river] and really reinforcing what we do in those areas. That'll be, I reckon, probably the biggest adaptation resilience tool.'
ER#3	'[In some places] the actual floodplain now is blocked off with all these water storages … there are people sitting in what was a floodplain tens of kilometres wide, [that] is now channelling water down a narrow slot between a whole bunch of ring tanks.'
FM#2	(**on appropriate designs for floodplains**) 'Built form that can deal with a 2 m flood or a 1.8 m flood. That's a fairly significant event. Bangladesh deals with it … they don't move *out* of the flood zone, they just build *for* the

	flood zone.'
LG#3.2	'I think the "run away from the hazard" … should be your last option rather than … your first option. So you can actually invest in making your home safer and if we had insurance companies on board they might actually be interested in reducing premiums for the rest of the life of the building if you undertake these measures. So things like – whether it's property raising, whether or not some kind of a barrier technology is actually feasible for your property.'
UT#1	'If you're going to build on the floodplain, build flood-resistant properties. So make the first floor basically just carparks and building above that so water can go through.'
ER#1.1	'If you're going to build a house in an area that might flood to a metre or whatever else, to use a style of construction which is effectively floodable on an intermittent event.'
LG#1	(**on the importance of a long term view**) 'The agencies that are responsible for the flood plain – catchment management authorities – have that longer term view that it will rain again … It's understanding through the planning scheme that if you do allow a residential development to be split off in a flood overlay, just because it hasn't flooded there for a number of years, that it's still going to have that impact of potentially being flooded, which it did. There's no doubt about that but because of these extremes they were allowed to go in there. Councils were leant on by the community to allow a subdivision to go through so they [built] housing lots and lifestyle living next to a river … it's very picturesque but you also need to understand that you're going to get flooded. So it's that sort of challenge that we've got with the climate change, is not forgetting the lessons learnt as time elapses because it does flood again.'
FM#1	'Climate change says that … we'll have more extreme events … Therefore, we need to be perhaps raising the bar as far as, say, planning activities, that sort of thing. You might've had 100-year flood overlays with a safety margin. Maybe under a climate change scenario, that safety margin gets called into question and you need a bigger safety margin. Certainly the floods that we had in January 2011 seemed to break all records and flooded a lot of houses that were recently granted building permits under a reasonable scenario'
FM#2	'We built on stilts and then built underneath so a lot of the houses around Graceville and Sherwood and those sort of places were high enough when they were originally built but then approvals were [given] to develop underneath enclosing in and those are the areas that got damaged.'
ER#3	'Where climate change compounds things is that during the lengthy dry periods more development occurs on the floodplains because people – these are land planning decisions – sort of forget that these are parts of systems that are connected by water. '[A reason there's been] 'a lot of the recent damage in floods is that there's been a lot of poor planning on flood plains, forgetting that during wet times that a lot of water comes down. Most Australian residents – the discharge is not in the main channel, it's out on the floodplain.'
LG#3.1	(**on reversing past planning decisions**) 'Once land is non-public, it's a very hard thing to undo.'
FM#3	'Melbourne's not so much a problem. I mean, that's got pretty strict regulation. The reason it's got strict regulation is because Melbourne Water is spending so much money bailing out the bad planning decisions of the past … there were something like 27 houses allowed to be built in a flood-prone area because of bad planning decisions. Now Melbourne Water is having to buy them out and it's costing tens of millions, well, I think it's $100 million, to buy all this out. That's just a simple bad planning decision, just one, and they know how much that costs them to undo it … they have to buy it all back and demolish the houses.'

LG#2	(**on rebuilding to improved standards after floods**) 'Our current standard … is 1 in 100 plus 500 mm freeboard … to be able to rebuild your house in an already approved area. 'That village obviously got inundated – which it has done in the past as well. A lot of the houses there are close to 100 years old, if not older. A lot of them were destroyed. So if they had to probably rebuild, as part of the new conditions, it's just a normal development construction requirement. 'I don't think council has any right to prevent [rebuilds]. It's a bit after the fact … I don't think we'd have any control in saying, "No, you can't build your house again."'
EM#2	(**on restricting development in floodplains: issues**) If someone owns a piece of land before you change the planning scheme, if the person had a reasonable expectation of being able to develop that land and the government then puts restrictions on the development of that land, then the question is, what level of liability of compensation should the government pay if they're actually going to stop you from building on that land?
EM#2	'We're actually talking about, under the resilience strategy, people taking responsibility for their own issues … So if someone says, "Right, here's a piece of land … I want to … undertake this sort of development and I am willing to take the risk and I will meet all costs associated with me building there and being flooded" … Surely why don't we [let them] take that risk? Of course, the standard problem is then you sell the property and someone else didn't realise that it was going to flood and they didn't realise what those potential problems were … people need to be appropriately informed. Obviously there's methods like putting those things on land title and tenure to advise people of potential risk and threat associated with that. But if you then legislate for that and someone says, "Well gee you've now reduced the value of my property by doing this," is the government liable for compensation for the reduction of the value of the property?'
ER#3	'Particularly the case in the coastal development areas – the Gold Coast, Sunshine Coast … most local governments get applications to develop … they'll look at them and they'll say, "No, that's not appropriate given all the environmental concerns" and reject them. Then they get taken to court and one of the councillors that I've worked with closely said that nearly their entire budget was consumed with defending land applications. So most councils, I think, are pretty much under [pressure] to try to manage development and don't really have the resources to really put behind preventing. In the case of the coastal developments, the state government in Queensland ended up stepping in. But we don't have very strong controls over development on floodplains, and clearly that's an area in a changing climate [where] we're going to need really tough legislation both at local and state government to make sure that floodplain planning is consistent with the view that these areas are going to have water on them. If you're going to allow activity on it, it should be the sort of activity that well, it won't matter if it goes under water every now and then; it won't do any damage and people won't be at risk.'
EM#2	'Better planning is useful but … there are competing priorities.' [NB the competing priorities discussed by EM#2 are included in the section on cost effectiveness.]
LG#3.1	'Flood prone with what likelihood, from what source? It's part of this whole what is Q100? What does 1 in 100 mean? Will the climate really change? There's a whole lot of arguments to be had before you finally get to that point where something is designated as a floodplain for planning purposes. Then you've got the question with how do you deal with the current owners of the land.'

FM#2 (QLD)	I don't think climate change is adequately reflected in planning schemes. SPP 1/03 may try to deal with it but it's that – I think the problem is we don't have enough certainty about what we need to recommend. Our climate models aren't telling us how the risks are changing in individual catchments with the climate change.
FM#3 (VIC)	'Most of the time you've got a flood overlay but you've never actually put it onto a planning scheme … what's missing at the moment is any sort of oversight.'
FM#3	'How do you plan for something that's uncertain when we're doing a bad job now planning for something that is certain?'
FM#3	'One of the problems with a strict planning system is that you're actually shifting responsibility from the private entirely to the public domain. You're saying to private developers, "Well, by us giving you a permit we're telling you that it's safe."'
FM#2	'One of the reasons that flood studies haven't been previously published … is that councils might be exposed for making decisions which were in a sense negligent … If climate change is going to dramatically increase the risk of flood … and the council doesn't take account of that, are they then negligent for making approvals for developments in areas which are going to be underwater because of sea level rise for example? Or increased storm surge risk or flood events?. LGAQ would often raise [that] there are some indemnities … provided for producing flood maps. I think NSW offers a statutory protection for local government to cover this issue.'
LG#1	(**options to build on land not subject to flooding can be limited**) 'The only bit of [the town] that would have been out of water is … a doughnut around the hospital, a length of about 400 m would have been the only area that would have been out of the water.'
LG#2	'There's areas [around here] that could still be developed [that are flood free]. However it's very widespread … It's actually being able to provide the services of gas, electricity, water. Which would be unaffordable at this stage unless the developer pays for the infrastructure. Because it's so widespread. You have hilly areas but most of the area … is a floodplain … I think going back through our land rezoning and processes, we need to in-build more before we move back out.'

5.4.6 On the appropriateness of the 1 in 100 year event standard

FM#3	(**appropriate planning standard to deal with climate change uncertainty**) 'The difference in stage between a 100 and 200 is usually pretty modest, just because of the structure of floodplains. I actually think you need a slightly different approach to it altogether [rather than changing to a more conservative planning standard], which is to say that the higher the flood gets the more private responsibility you have to take. What's happening, because government makes predictions so that you can draw lines on maps in planning schemes, government's taking the public responsibility for risk. They're defining the risk and they're telling people what they can do. 'Because of climate change and because we're uncertain about big end floods, then what are we going to do about that? Well, the first thing we shouldn't do is weaken all of the planning constraints and stuff down at the bottom end with the five-year floods, 10-year floods. Who cares if your five-year flood becomes a four-year, or your 10-year becomes an eight-year? Well, it doesn't matter. Don't change anything down there. 'At the big end, at the 200-year end, what they should do is … make people aware of the risk, and it's all about information. You build the risk into the private responsibility so they either have to have insurance or somehow they can't get away with not taking responsibility for the fact that they live in that place. That applies to second and third generation owners as well. The best way you make them aware is through cost, through the fact that you have a covenant on [the land].'

	'If a 200-year event actually happens, the reality is it's going to be so catastrophic that government's going to roll out and fix it anyway. Well, that would be my view. The problem with flooding is not the 100-year event so much as the five- and the 10- and the 20-year events – you've got to make sure that people are out of those areas. In a lot of the state they aren't.'
UT#1	'We're going to actually reduce the high-frequency flooding, these are the small flood events. So we'll actually wipe out the 1 in 100s, maybe [using] upstream storages and things. That's great, but eventually nature doesn't do a 1 in 100 event, it does a 1 in 1000-year event or 1 in 10 000 year event. Then we'll go, oh all the people died. Why? Because we thought we'd "stopped" flooding. You didn't stop flooding, you just stopped small flooding. Then we get a complete shock when the big one comes because people are actually less ready and less prepared and die in large numbers. So I think that there's a whole problem in our psychology of how we think about flooding.'
UT#1	'I'm not convinced that we should be building on flood levels below, say, one in 300 or so … maybe building codes could be introduced to say, well actually between one in 100 and one in 500, if we do a two-storey house and the bottom storey of the house is only kept as garage, well actually the loss cost is probably not too bad. It's about thinking about what are the acceptable losses. It's not about having no losses but I'm not sure society can afford that because of land space. But it's about saying, maybe, what is acceptable loss?'
FM#2	'Given the length of time that a house [lasts], this 1 in 100 is a bit underdone because these are not investment decisions that just last 100 years. But once you build a town or build a development, it's going to last thousands and thousands – you know, London is still there … Unless you just say, "Well we're willing to take that damage once every 100 years", which … may be a reasonable proposition. But people who buy those houses need to have the information available to them of what that relative risk is … people don't know that "I should be getting a discount on this property by the river because it's going to flood one day".'
LG#3.1	'This whole debate over Q100 and what is a 1 in 100 year event … from memory they had a consultant that came through at some stage and drew a line on a map and said that's your Q100. Then they had a different study that gave them a different line that was below it and potentially opened up some new areas for development but then there was all this uncertainty over how do we model it … Then throw in climate change, which again is starting to impact more and more on the planners and their recommendations to council in terms of future zoning of areas.'
LG#2	(**on future development risks**) 'What we actually do now with our current development under our DCPs is that they've got to nominate what the 1 in 100 level is, and they have to allow for a 500 m freeboard to build above that 100 level … with those conditions there's also problems. I mean you're still building on a floodplain so you're changing the behaviour and the character of the actual floodplain and those within that path. So that that needs to be looked at as well. Most of the time when development applications do come through, they're not looked at large scale. They're looked at for that area alone. Potentially in the first 10 to 20 years of continually doing that you probably won't see much change. However, in the long term you will. You'll change the actual behaviour of the flood and the flow paths, the natural flow paths that do happen there. So you'll … see pre-existing houses that have never had issues of flooding before actually start to get flooding.'
ER#1.3	'In America, New Jersey, they're actually doing floodplain management based on their 1 in 100 year flood levels. But they're also allowing a 25 per cent addition on top of that to sort of account for the likelihood of higher events in the future … that would certainly be a recommendation to take that into account … we're going to get the bigger events so whether it's raising houses up by another degree. Account for what you think the flood levels are going to be.'

5.4.7 Reducing risks for existing development

INS#3	(**on reduced property value**) 'After the event, everybody's warned now. My house will definitely have less value. I'm just hoping nobody knows about it … I would also say if anybody were to sell a property, they would need to show what the floodplain is. So the new buyer is aware. You need quite tight controls around that … So you can't flog your property to some unknown, unaware person.'
EM#2	'In Queensland, a lot of houses have been built in underneath and they've never been approved for being built in underneath. Then they get used for things that they haven't been approved for … people spent lots of money … putting assets in place … 'In Queensland now, if you advertise your property, you might have a five-bedroom house but it's only three bedrooms upstairs … unless they've been approved, [the extra bedrooms downstairs] can't be advertised now.'
INS#1	(**residential properties**) 'So there are other simple measures like the elevation of existing property is a good one and that's certainly done in areas with the states with some success. So really the argument we've got for mitigation is that where you've got an existing town that is at risk from repetitive flooding, that its levees, elevation, removal of properties in extreme circumstances, sort of the layered approach you need to actually reduce the physical at risk return period for these properties in those locations. That's the only way that insurers will be able to insure those properties.'
INS#3	'I'd probably have a multi-pronged attack. I would ensure that if your house is in a known floodplain, then the next time you do any renovations or additions to your house … you have to comply with the new building code regulations … the properties that were, unfortunately, historically built in the floodplains, then I would be very open with the owners and show them what their flood risk is. Explain to them that every 20 years, they should expect a wipeout. Explain to them – give them all the data the government has and the council has. Be very open with the individuals, so inform them about their true underlying risk … Then, potentially, whether it be a social gesture of helping them relocate their properties. Whether it be subsidising levee fences around their properties. Yeah, Australia's a very socially aware country, and we pay a lot of taxes. So to a certain extent, they can choose to help or not help these customers as each council sees fit.
UT#1	'Jack the house up as part of the response. So that next time it floods to the same level as this year or as last year, [the flood] will actually be under the floorboards. I don't see a problem with that because that should be low-cost damage, basically whatever is stored underneath. Which means the family can move back in quickly, restore their lives quickly, go to work quickly, go to school quickly, restore community functioning.'
LG#2	'There's plenty of management plans in manuals they're developing and building within floodplains and flood zones. The recommendations from those, they're quite achievable. Whether it's raise the houses on stilts, things like that, to allow water and the flow path to actually continue. Rather than building and obstructing the actual natural flow path.'
FM#1	'We need to take a higher risk profile position in terms of protecting assets, I think. We've done that by putting [ring] levees around the houses [in the Loddon] rather than saying 'well you can't live there anymore'. It's better to accept that they're going to get flooded and they still might have access problems, from a short-term perspective, but long term their house will be still intact.'
FM#3	'You turn to these legacies of the past and the rule is that the public pays. That's all there is to it. You just can't penalise people for bad policy decisions which were made in the past … If there are planning permits, then you've got to buy them out … a lot of the planning permits are … local decisions of local councils. They have to wear the cost of that as well … [or] you

	can do ring levees. It might be cheaper just to put a little levee around it and then you get the landholder to contribute to that as well … and you've just got to put in incremental policies. So, for example, you flag a property. Every time a property's about to be sold, you'd act. You'd say, well, there's going to be a new covenant – and this is a real social justice problem, in why should be we impose new restrictions on people that weren't there when they bought the house.'
FM#3	'A levee around a town, that's fine. No one's got any problems with that and it's well designed for a 100-year event and it's maintained by the community, by the beneficiaries. Certainly in Victoria town levees are not contentious. You can put up a ring levee [around individual buildings].'
FM#2	(**waterproofing**) 'Build resilience into those houses … they've just taken out one sheet [of gyprock] and they've put in marine ply underneath the dado rail so next time it comes up to 1.2 m the sheets can stay there.'
FM#2	(**on the mining industry**) 'What's going to help Queensland coal mines reduce the amount of floodwater retained on their sites ... They've got to change their water management systems. So rather than try to deal with water that's bucketing down, pumped off the site through a straw, they need to have some gravity feed relief gates. Sort of valve situation so they can release large volumes during the event so that the increase in salinity is diluted sufficiently to be with their simulated capacity of the waterway. Now that's months and months of work. There might be some design issues. [The Queensland government is] working with the mining sector to identify what those designs look like, how they can be regulated and what the new regulations would be. How we measure salinity in flood events and those sorts of things.'

5.4.8 Relocation

INS#2	'I think Australians have this idea of, we will not be moved or we will rebuild, rebuild … should [we] be making those tough decisions … and not waiting for something horrible, like the Lockyer Valley, to occur. Actually doing it before those things happen, based on the information we have about what could happen.'
INS#2	(**on rebuilding another house in the same spot as one that has been destroyed**) You can advise people that this is what could happen, but you're presuming that they're going to act in a way that is long term, which is not always the case. The government has to make that decision because they're the ones who can.
UT#1	'In Australia for the last 100 years, [we] actually have been buying back flood-prone properties. In some council areas and some states, there has been quite an effort on that. That's very good and should keep going, at least remove your most frequently flooded properties off the floodplains.'
UT#1	'It's actually the [political] will to spend it on that problem because it's an infrequent problem. It's actually the poorer people live on floodplains. They've got the least vote, so who cares? It isn't a money problem, the government's not short of money. If it likes a project it'll find a million dollars, but it's not a popular project, doesn't get a lot of votes.'
UT#1	'Governments regularly put covenants on properties so they can't be resold and have to be sold back to government. That's done for national parks, it's done for freeways, we have methodologies for actually doing that, we don't have the will to do that.'
EM#2	'Councils and governments have been doing buyback plans for those places that flood on a more regular basis … done in Brisbane but it's a slow process of buying back those particular inner city places prone to flooding and subject to flooding.'
EM#1	'There has been a scheme operating down on the Lower Loddon … about voluntary buy-backs.'
LG#3.2	(**on the Grantham relocation**) 'The council, [which is] essentially at the centre of this one is now having some real

	difficulties convincing people that they should in fact swap their lovely riverside block that they lived in specifically because it was the more bucolic part … [people have] been told that this was a 1 in 250 or a 1 in 500 event. So not many people figure they're going to live for 250 years, so it's probably safe to go back. But also the hill that has been allocated as the new estate in Grantham, it's a bloody ugly piece of windswept patch of nothing. There's barely a tree on it … some have jumped at the opportunity, offloaded their property down below and completely committed to being on the top of the hill. There are others who are digging their heels in and saying under no circumstances will they move. But they're having difficulties getting rebuild permits to rebuild on their piece of land down by the river.'
LG#3.2	(**on encouraging relocation**) 'Big buckets of money sometimes helps. That's about it. It's very difficult to rezone and force people out. Once you go through the lengthily appeals processes and then the appeal on the appeal and then the review. You absolutely have to convince people that it's voluntary.' [see also Section 5.4.21 below]
FM#3	'It's always the toss-up between the cost of protecting them, which is a public cost and the risk of failing to protect them against the cost of just buying them out and removing them.'
LG#2	'I don't think it's a silly option. I just think it's very unaffordable … all local governments, especially rural outside of metropolitan areas, are going to struggle with funds and competing general revenue funding. This is competing with roads reconstruction, things like that. I don't think they'd ever be able to afford it without either federal or state kind of amnesty or buyback scheme. 'I think you'd have the local community in an uproar because their levels of service would obviously be impacted upon, allowing that additional income to purchase someone else's house. Just to maintain a flow path which probably shouldn't have been built on in the past [when] they didn't have those levels of development restrictions.'
FM#1	(**on the social impact of relocation**) 'When governments invest money and buy out and we're actually providing a new life for a proportion of the community, there's a whole lot of other people that remain and there's a real grieving process because they see over a very short period of time, a large number of their friends and contacts and what have you, moving away. So when you change the fabric of a local community really quickly, it does have some quite negative outcomes in terms of how people behave. I still don't know now whether or not this is good public policy. 'When we put these other properties back on the market and other people buy them, that will be the real settling-down period, but it takes a hell of a long time for … it's really hard for communities to get over these things.'
FM#1	'I'm absolutely certain that what we've done there will leave a permanent beneficial legacy, both in terms of protecting assets and changing land use. That's what we set out to do, so even though all of the social stuff has been quite an eye opener for us in terms of the depth of the passion and everything, we have achieved what we set out to achieve and that will be a long-term benefit … I think in another year's time, we will be able to claim success in that local area as well. At the moment they're still a bit fragile.'
ER#2	'I've heard people who live in these areas say that one reason they really don't want to leave is because after the floods they just know everyone in their street. Everyone helps out and they share their tools and people come and help do something in the garden or fixing up houses …'
ER#3	'In some parts of lower Brisbane, around Oxley Creek where there are houses built right next to the river, every time it floods they go under. Some of those properties,

	they're considering buying them out. I think in the longer term that's probably a cost-effective strategy.'

5.4.9 Structural measures

INS#1	'Brisbane flooding – a lot of it can be controlled by gates, floodgates that prevent backflow and issues like that. So particularly on some of the larger creek systems that flow into the Brisbane and the Bremer, you can prevent a lot of the peak flooding just by simple floodgate systems. At some point those get overwhelmed though, so it's not going to prevent every flood but it will prevent quite a few of them.'
INS#1	'If you go to an area like Roma, Charleville, Saint George, Dirranbandi and places like that, then you're talking about flood levees along river systems, and the same sort of thing in Emerald.'
INS#2	'[Levees are] one of the last options in the line – so you've already kind of gone past the planning point. That's too late. You can't get people out of the area. You can't make sure that everyone's house is above the flood levels. So, when it comes down to it, we would support a levee if that was the next best thing, I guess … the experts, our tech guys, kind of think that levees have a lot of down-sides because of the impacts they can have down- and up-stream. You can cause flooding. You can, say, stop flooding from one area and the push flooding into an area that never used to get flooded and there's all sorts of things to think about. But it would come down to a cost-benefit analysis on each case. If it works putting one in here, depending on who's at risk, what kind of risk …'
LG#3.2	'Coastal erosion's one of those really interesting ones where everybody wants a sea wall to protect against erosion but they don't want it built well enough that it's going to impact on 'my view of the ocean'. Rivers are much the same. It's incredibly expensive but it's not actually that difficult to build levees along the riverbanks as they did in places like Mississippi … 30 or 40 foot high concrete levee banks that keep the water inside the system, but they're really bloody ugly.'
LG#2	'Our rural levees are more providing protection up to a certain height … They basically give us time to evacuate those rural areas and stuff like that. So when they do break not much damage to infrastructure or residential properties occurs – they're more there to probably help us out in regards to timing.'
LG#1	'If you were on the land subject to inundation, [you would be encouraged] to put a ring levee around your property or … if you get a building permit and you're on the land subject to inundation, you're required to build above the 1 in 100 year flood level. But certainly I would be – personally, if it was me building on the floodplain, (a) I wouldn't build there, but (b) I'd put a ring levee around my property.'
ER#2	'Planned or managed adaptation … should concentrate firstly on identifying and securing your most vulnerable assets. So obviously there are going to be some things that are so at risk from … changes to flooding that you really, really value. If they can be moved – could be moved or if [something] else can be done to protect the site. I agree that there are always going to be some things like that that really need a hard engineering approach.'
LG#1	(**on the limitations of levees for mitigating climate change**) We can protect that infrastructure within the town but the problem is that you're still going to have essentially 3500 people isolated within that town, all requiring services, requiring sewer, power, food, water, so on. In that regard, the levee bank really only protects the infrastructure within the town. If the people are going to be stuck [within the levees] for an extended period of time, be it four, five, six days with no food coming in and something happens outside the area which may affect power supply, services, provisions for these people, the community within. We can protect the infrastructure by having a higher bank, but if we've got to contain 3500 people in that little island for four

	to five days, that just can't happen. So [the town] cannot be protected from climate change because of that compounding effect.
UT#1	(**improvements in levee technology and management**) US Flood Control, which is a private company … build flood barriers. We've actually bought two for trial, which are big long tubes that you just basically fill up with water and you can build those to a height of about 2 m … the barriers could be used for, say, inland flooding where the flood heights are relatively low really. You could deploy the barriers and build artificial levees, easily, simply … we have maybe come forward as a country because we did actually see at these last floods some deployment of temporary barriers. Which was a step forward over the 1920 sandbags, but there's a lot of reticence to really get into that here for some reason I don't understand.
ER#2	'There are probably possibilities to make some of those [flood mitigation] structures that are mainly for human benefit be a little bit more ecologically habitable as well for other species.'
LG#1	'[Levee setback] is almost like a buffer type effect and that's essentially what's happened down at Benjeroop which is part of the buyback. I would love to see that occur back down the floodplains through our area because that would pick up the typical flood events too. I'd really like to see that happen … Because it just makes so much sense to allow that flood to spill from the stream to be retained in that broader area and slow the flood right down as opposed to channelling through these banks … It just makes sense for that to happen and if you look at the topography, I guarantee before white man's settlement that they just would have done exactly like that, it would have been a slow-moving flow.' To achieve levee setback, 'potentially [buy land], allocate a reserve or an easement'.
FM#3	'One of the historical problems in Victoria is that they've usually built the levees along the rivers, which are in parks – often in national parks. Whereas in the Lower Goulburn case they would like to move the levee away from the river out on to private land, on the edge, and the policy at the moment is, "Yeah, good idea. But who's going to pay for it?"'
EM#1	'Victoria already has a lot of flood mitigation works in place. Some of those will obviously need to be reviewed given the different scenarios, the potential for some of those scenarios to happen more frequently. So if the 1 in 100 year flood becomes the 1 in 20 year flood, it will necessitate the need to upgrade mitigation works.
LG#1	(**on levee ownership and maintenance**) 'The community wanted to hear that DSE or someone's going to own and maintain those banks [rural levees on public land]. The reality is that won't happen and I think that will be the perennial issue or question that will never be solved, is that levee bank. Unless all the banks were shifted back on to private land, then you're going to have issues about, "Well why haven't you maintained your bank? You flooded me out because you didn't maintain the bank on your property." So I think [that question] will never be answered.'
LG#3.2	(**on levee challenges**) '[A] famous levee bank here in Queensland is the one at Charleville where the Warrego River causes major flooding … The problem was when the rain fell in a different place and ran down a part of the countryside called Bradley's Gully it actually got locked into town by the levee bank that was keeping the river out … they actually had to demolish part of the levee in the end to let it flow. But that's now added some $28 million to the cost of the levee bank at Charleville so they can ensure that that sort of flooding from Bradley's Gully doesn't happen again … there's another couple of potential [floodwater sources] that could still run from the wrong direction and back up against the levee bank if the river's high … if you're not going to encircle the town with a levee bank, your answer may indeed cause a bigger problem if it's different from the most expected event.'

LG#3.2	'There's some extended levee debate going on about "Do I need to better levee my town so that they don't have to evacuate?" versus Farmer Joe who has built a levee around his cotton field is actually flooding my town deeper because he's keeping the water off his property but it's now increasing the depth levels … but some of those debates and discussions, they're piecemeal, I think. It's not a major coordination of thinking and activity.'
LG#1	'I've heard old people's talk about the flood in 1909, where they had a similar peak discharge … it just flooded over, ran the whole way right through and just poured into the Murray River and away it went. It wasn't held back behind levee banks because levee banks … with the flood transition, we had to pump the water back out over those levees back into the natural carriers.'
ER#3	'You can have the best levee systems in the world and ultimately something's going to go wrong; there'll be a flood bigger than predicted … While levees clearly work for most of the floods … they can lead to a false sense of security; that if you've got a levee then everyone's going to be safe … everyone then is really complacent about all the other things [they can] do.'
LG#3.2 (QLD)	(**on levee regulation**) 'There are some provisions for local regulation. But again, when you're talking about broad acre country like that, we don't have and can't afford to send somebody driving round to check whether or not levees have been built. Even harder than that is to determine [whether] they've been raised, which is again one of the issues that's being talked about in many places: "Oh that levee's been there for 100 years" and somebody says, "Yeah, but when I was a kid I remember it was only half a metre high.' Then the common argument is that it just seemed higher when you were a kid because you were smaller. I've heard that run in a meeting once before.'
LG#3.1 LG#3.2	'We celebrate a lot of our dodgy, unregulated, hastily constructed levees.' 'It's released to the newspapers by the council or the state government, "Look how quickly we've thrown up this levee around a town like St George. And by the way can we have $300 000 so we can pack it down and finish it off properly now that the water's gone?"'
LG#1	'Most of those levees have been pushed up in haste at the time well past – years ago. Probably put up originally by horse and dray and now been topped up by earth-moving equipment. The integrity or the structure of those banks is questionable. The material that has been pushed up is questionable now. Whether it's just been the topsoil, it's blended up with existing material. They've got trees growing up through them and they've got rabbits in them, so on and so forth. There is no doubt that they provide some benefit to not only the land abutting the levee or the land it's sitting on, but it's also the protection for the subsequent landholders behind and beside.'
LG#2 (NSW)	'They are to be licensed and maintained and provided at that licensed height … it's regulated through the NSW Office of Water.'
FM#3 (VIC)	'Under the *Water Act* you can't [construct a levee without approval] and the reason is that they always affect somebody else.'; '[Ring levees are] regulated, but only because they're so dangerous. Ring levees are really – any levee's dangerous because you get 3 m of water sitting behind a wall with you huddling inside in your house, it is dangerous.'
LG#3.2	(**on pseudo-levees to protect agricultural land**) 'Particularly [in] Southern Queensland there's a fairly large part of the country down there that's got levee banks. Some of them are for flood irrigation … they're technically levees to keep the water inside a paddock but if there's a lot of water outside the paddock they do the same job of keeping it out … So the owner of that cotton farm will be saying, "Well this isn't a flood levee, this is a growing levee."

FM#1	(**on levee construction difficulties**) 'We did have difficulties … building [ring] levees on public land. The unique difficulty down here has to do with native title because there's a native title claim on all the public land through this area. Of course, if you do works on public land while there's a claim, it extinguishes native title bids. So we've had an awful hassle where properties get really close to the edges of public land, let alone building right on them, and try and construct levees around that. 'We've actually found one house completely built on Crown land. 'We've [also] had difficulties trying to join up our government-funded levees to privately constructed ones that maybe are of a higher or of a lesser standard. 'It actually turned out to be a real can of worms. It's okay for the individual people to [build ring levees around their property]. It's easy for them. For government to do it, there's more strict protocols that we need to go through that we under-estimated.'

5.4.10 Infrastructure

UT#1	(**betterment of**) The water industry tends to have very fixed infrastructure and often very old infrastructure … the foundations of the cities were around a water supply, so a lot of it is very expensive to replace … people that have had flood impact [have] tried to replace their damaged infrastructure with stuff that's more flexible … old cast-iron pipes, they've been replaced by plastic pipes which tend to adjust a bit more for ground movement and have lower rates of failure. In our own case, as we've done some of the big capital upgrades now … raise critical components to higher levels in the plants …submersible pumps.
UT#1	Queensland Urban Utilities deployed a team to support Mitchell, which was impacted by the floods and I know they did prepare a report at the time and they just haven't followed it through, suggesting a pilot betterments as part of the restoration.
EM#2	'The damage done to the road network and then to restore that network, all the bridges and those sort of things. You know, to restore them to a level better than they were before which is always a perennial question since treasuries have always said, 'No – you restore them to a level of what they were.' But the betterment clause does exist. There is a provision to enable things to be restored to a better state but its hasn't been used.'
UT#1	(**good design of**) Rockhampton, as a good example. For some complete mystery of history, they had an engineer when they built their wastewater plant who actually built it to withstand flood events. So their treatment plant kept functioning virtually through the flood because they'd actually built their infrastructure to the right height, the right design to actually have minimal flood impact. So someone in past history had huge foresight and insight, and obviously had some money to spend and built properly. So it can be done.
EM#1	'The real issue, I think, is around the flash flooding in urban areas, because that's not necessarily an easy thing to mitigate … [people] have been trying to mitigate a lot of those issues through drainage schemes and improvements in drainage. If the five-year flood becomes the one-year flood and we need to upgrade all our drainage by a certain percentage, etc., that's a very expensive and a very difficult thing to do. I see those issues as being hardest to mitigate.'
LG#3.1	'The whole betterments thing, the works program and do we need to upgrade the drains next time we're doing pavement work so they can take those more intense downfalls.'

LG#2	'[Developments] provide a level of prevention for 1 in 10 ARI for stormwater infrastructure. From the report that ACOM put through I think that we'd have to cater for a 1 in 28 [to accommodate climate change] … That was a report done to … review what is potential … currently our normal standard of a 375 mm pipe may have to increase to a 450 mm pipe. So obviously that increasing cost in development [would] cause a bit of a stir with developers and obviously maintenance costs as well and replacement costs … It's for councils to elect what level of service to provide … At the moment I don't think we can, as a local government, increase our level of service because we don't have the funds there to actually do that. I think we struggle to actually have the funds now to maintain what we have in there.'
FM#2	'I'm not convinced that we're doing sufficient on resilience of transport infrastructure … given the size of the bill.'

5.4.11 Velocity

ER#1	(**impacts of climate change on floodwater velocity**) 'The science is indicating that we're likely to get rather than more extreme weather events, or severe weather events, the weather events that occur are likely to be more intense, more severe … So therefore the assumption that we're working with is that we will have events that have more energy involved in their dynamics. So therefore we're looking to match the way in which the energy of those events is handled by the landscape, by landscape function.'
EM#2 (QLD)	(**on the effects of velocity**) 'The force of the water and the flow was just so incredible. There was a half-tonne safe found 22 km away from the house it was ripped out of. You know, so some of the water flows in Brisbane you know, water was moving at 9000 m^3 per second in the main part of the river here in Brisbane City. So essentially anything that was in its way would actually be taken out. The fact that the bridges stand up is a testament to the way they were built … The vast majority of the damage was to government-owned infrastructure, state, local government infrastructure. Roads, bridges, those sorts of things, rail – you know, the really big-ticket items.'
FM#3	'The upper catchment, of course, has more power, more erosion but it actually sort of peaks mid-basin … if you can slow the flood peaks down and you can dissipate that energy, and you can use vegetation, you can have corresponding environmental benefits and all that sort of stuff … the main in terms of public cost would certainly be roads. That's because the roads get scoured out by the floodwater going over the top of them. Bridges get scoured out and destroyed. That's all the energy. It's just a different way of thinking about it, but it doesn't really come up. So you end up having people do planning for flood extent and for flood inundation and duration and frequency.'
ER#1.1	'Channelising drainage lines high in the catchment basically gets the water out the system much more quickly so that as it hits the mid-landscape, it has a lot of energy. And there's a lot of it … I guess what we're seeking to look at is what will floods do in different parts of the landscape, and what's the best way to support the landscape's natural function so that it takes energy out of the system.'
ER#1.2	'The key messages that we're pulling out so far are that in the upper catchment, catchment vegetation helps to absorb and slow down water flow … so you have less water entering the catchments, that you reduce the extent of flooding downstream.'
ER#3	'Better floodplain vegetation management or stable channels … would have slowed the flood peaks down, dispersed most of the energy and most of the actual damage in that Lockyer [Valley] flood. There's some modelling now to confirm this that we could have avoided some of the actual damage to property and life and also reduced the environmental impact downstream.'

LG#3.1 (QLD)	(**on attention to velocity in flood studies**) 'Very little of the hydrology studies actually look at [floodwater velocity] … They almost all look at the bathtub model that the water miraculously just oozes up out of the ground for a period of time and then soaks back in. There's no movement of it in any of this modelling.'
LG#2 (NSW)	'[Velocity was] undertaken as part of our [overland flood] study, so more than just the depth … I mean that's basically what identifies your high priority risk areas. So part of our studies, we identified hotspots for improvement.'
ER#3	(**to reduce velocity**) 'If you spill water out on to the floodplain the … erosive power of the stream actually dissipates. … floods that actually hit bank full height have the most energy on the stream bed and are doing most of the damage to the banks. 'Stream power is not only a function of the depth and the width of the water, it's a function also of the surface slope. So as the flood depth goes up, the actual slope of the channel starts to decrease … The power is a function of the slope cubed. So a small change in slope has a big influence on the stream power. So once you start getting bigger and bigger floods the actual power – the erosive power on the bed actually starts to diminish. 'So really the damage is more likely to happen in the 1 in 1 year, 1 in 2 year events that are coming through and largely staying in the channel … one of the key things to floodplains is to spill the water out. The moment you can do that then you're actually dropping the power.
ER#3	'The problem is we've got a highly modified channel system where channels are incised … in the upper Lockyer now, some of those channels can take a 1 in 1000 year event down inside the channel itself because they're so incised … You've got to fix it much further up in the catchment. If you try to fix it down there you'd just destroy farmland'; 'The frequency by which [floods] now get out on the floodplain has changed and so some of the upper catchment stuff may require engineering – when I say engineering, natural engineering in the stream bed – to actually lift the bed height up so that the water does have the chance to spill out in some of these.'
ER#3	'Many Australian systems, particularly on the eastern coast, were what you'd class as chain of ponds … a lot of the headwater catchments would have been largely vegetative, largely chain of ponds. 'With catchment clearing more of the water now gets into a channel network and most of those chain of pond systems have gone … there's a lot of gullies and channel incisions. So most of the flow now is directed into the channel network and it's conveyed very quickly downstream; it's a legacy of post-European land usage of these systems. 'So to address that, what you really need to do is get in there and impede water, and impeding it with vegetation is the easiest way to do it … There are types of vegetation that are incredibly flood resistant, so things like Callistemons … withstand being flattened. 'This comes back to your climate question again – in highly intermittent systems a lot of vegetation actually grows *in* the channel, particularly between floods. So actually the *channel* is full of vegetation as well. So when you do get any flow down them, that impedes that water. It silts it up, traps sediment; does all the right things … if you actually modelled the hydrology with vegetative channels and banks you [could] significantly reduce the flood peak, delay it, and you [could] significantly reduce the intensity, the power of it. The moment you do that, of course, you stabilise banks, you're reducing sediment loss and damage to stream banks and erosion.'

ER#3	'You need to actually fix in place the upper catchment to slow and impede the water. By the time you've got down to the middle reaches of these things, most of the energy's in the channel and you've got no ability to do anything with it … that's where a lot of the productive farmland is – so there's not much you can do once it's midway down. What a lot of the farmers do is levee up their own property and push the problem even further down.'

5.4.12 A catchment systems approach and using natural assets

ER#1.1	(**resilient landscapes**) 'In an undisturbed landscape, the movement of the water would tend to be governed by vegetation in the upper catchments and access to the floodplains in the mid-catchments and lower catchments. So what we're saying is by establishing natural assets, we're looking to reinforce the resilience of the natural processes of the landscape.'
ER#2	(**on natural systems for protection of property and security**) 'I just don't think that enough serious consideration is being given to softer flood mitigation measures and the importance of ecological services for those … Given that places like the Netherlands are employing those methods quite effectively with much greater populations or densities of population, I think that we could definitely warrant investigating further here … Insufficient attention is given to the potential ecological impact of other mitigation methods.'
ER#1.1	(**on the potential for natural assets to mitigate flooding and storm surge**) 'Our focus has been on the way in which natural assets can be used to ameliorate or lessen the effect of floods – particularly the floods … How can you manage your landscape, and various parts of the landscape, in order to reduce the effect of floods, and the effects of cyclones through storm surge. So the kinds of things we've looked at have been … How do you reduce the energy of the flood or the storm surge. That's involved the way in which you manage upper catchments to slow flood, reduce the concentration of flood. In the mid-catchment, the way in which you can seek to hold water in the landscape for longer, and therefore reduce its energy that drains away. We've looked at both the physical things you can do to intervene, and also the planning interventions that might be appropriate. The scope of the work has been to look at what's been happening elsewhere in the world; anything that's been documented in the scientific literature, but also other experience that's documented on the internet.'
ER#1.2	We have a whole range of these recommendations through: • using riparian vegetation to slow the rate that water enters creeks and reduce flood extent and flood stage • using reconnecting floodplains to the rivers where they've perhaps been separated by levee banks in strategic locations • using those areas to store and gradually drain the water away. So again you're reducing the downstream flood extent. Those are the three sort of primary ones and we also have some around the storm surge … a certain amount of barrier by mangroves can be a particularly cost effective measure of reducing the impact of storm surge beyond the capacity that you would have with an engineered structure. Where you use mangroves you tend to have a much more cost-effective approach than relying on the constructed defences.
FM#2	'A little story of Cardwell – the story of Cardwell was there was a bloke who we thought might be dead who took to his boat – I think it was a catamaran – from the Cardwell Marina and went up a mangrovey creek and stayed with his boat and walked out with an undamaged boat because he was protected [from storm surge] by the mangroves – rather than bashed against the shore. People clear the mangroves for the views and then get washed away.'
FM#3	'[There's a] case around revegetation of streams … our modelling has shown that you can have an effect on downstream towns and areas by holding the water up further with revegetation schemes and things.'

ER#2	'I think there's substantial evidence to show how good the mangroves are as … bio-shields. It will be harder if there are no surfaces for mangroves to colonise. I guess that's the problem in places like Brisbane where the banks are all armoured and mangroves are seen as an eyesore. So, again, that's education and getting people involved who will address that. It's a very long tidal influence, the Brisbane River, so the actual need for mangroves would go right up into the city. But yeah, they were all cleared. There are places where they're regrouping. My understanding is that in most rivers, estuaries – that mangroves are expected to move further inland. They're one of the so-called winners of climate change, at the expense of salt marshes and mudflats.'
ER#3	'A model exercise [was done] for the Caboolture River … if they'd had vegetated corridors along the Caboolture River, the actual flood heights would have been a lot lower than they were … So I think there's certainly no question that managing vegetation better would have been a … key flood response. As the climate changes and these intense events become – longer dry spells, more intense wet events, this is going to be a key weapon to that flood resilience.'
ER#1.2	(**additional benefits of retaining water on properties for longer**) 'Groundwater recharges of aquifers both in terms of the general landscape, and particularly for groundwater dependent ecosystems. It's an important process. As well as slowing down the water in the landscape, reducing the amount of sediment that runs off into the creek. You're holding that on the landscape as it's silted out by ground cover and vegetation. So also, it has benefits for the agricultural users who are retaining the valuable top soil on their property as well as preventing it entering and damaging the creeks and marine estuary systems.'
ER#3	'If you look at … the Lockyer … where the groundwater table is over-used. Putting in leaky reservoirs and putting in these impediment basins, maybe sacrificing some of the more marginal flood plain land in the upper catchments where people have got a little bit of grazing and stuff, and allowing floodwater to pond up on that. It's a very, very ideal way to recharge aquifers and certainly that's another benefit that we really haven't been able to quantify and capture either.'
FM#3	(**on obtaining environmental benefits from floods**) 'Often people have this sort of vague view that it's a good thing to have floods on floodplains – which is the case – and people talk about reconnecting rivers to floodplains. What's most important if you think of most of the floodplains, like the Lower Goulburn one, 90% of it is just pasture. It's just grass. Flooding grass really has no environment benefit. What's important is to get water into wetlands and get water into places where the water will stand and have an effect. That's quite a different – and they're usually the lowest parts of floodplains. But you need to flood the entire floodplain often to get the water out of the back into those wetland areas. So whenever people say, "It's important for the environment to have flooding", it's important to reconnect floodplains … If you look along the Murray and along the major streams, most of these little side channels are all blocked off. Or the levees cut them off, or little check dams and regulators. People don't want water going back into their property. You just build your levee across everything. All the floodways and the anabranches … that used to feed water out on to the floodplain are all blocked off. 'There's a bunch of ways to get water to those wetland areas … you often don't need 100-year flood events to get there. You can do it in a five-year [flood] and this is what environmental flooding is all about … You dig channels or you drop the barriers or you manipulate things so the water can get into those wetlands at lower floods … you can often do all sorts of things to increase the effectiveness of smaller floods and … You [can] just put a little gate in the bottom to reconnect rivers to floodplains. It's very little … about allowing giant floods out [on to the floodplain] because they don't actually

	have much more environmental benefit apart from filling big lakes … So it's understanding what is the function of floods of different sizes.'
LG#1	(**on the potential for opening natural floodways**) [on allowing water to spread out of the main channel and flow into anabranches now blocked by levees to increase storage capacity] '...some of those options...open up some of those traditional anabranches that occurred down on the floodplain, so they're opened back up to allow that flow-through to occur. Currently that's not an option... it's about putting a structure down at either end [of the anabranch] because it's so flat... It's about putting a regulator on either end ... to enable that flow-through to occur. Now that would be a fairly significant regulator because if the Murray is in flood - because of the flatness of the land it does have the potential to spill and actually run backwards'
ER#1.1	(**on the potential to block natural floodways**) One example we've got from Healthy Waterways work, from the Healthy Country Program … there'd been a natural levee in the river. That levee was breached to allow the floodplain to drain quickly into the main watercourse and add more water and more energy to the river, and to drain the landscape. So what was done was to in fact mend that breach, and allow some – using drainage pipes, small bore, I think only about 100/150 millimetre drainage pipes – allowed the water from the landscape to drain through a pipe back into the river much more slowly. So that during the event the river would take its normal load. So the floodplain, instead of being able to empty quickly into the river, was allowed to drain much more slowly into the river over the space of days rather than hours, to feed the water into the river more slowly. Now the implications of that is there's more water in the river for longer. However, it smoothes out the effect if you like, and dissipates energy from the system. So you've diminished its destructive capacity. Now there are some direct things you can do to work with natural levees that have been breached, or in fact levees that have been put there to, I guess, try to reduce energy. However, they have to be thought through so [you don't] cause damage to life and property elsewhere, or damage to natural landscape so that you lose your resilience.
ER#1.2	(**where and how much revegetation is needed to mitigate floods**) 'The science is not able to tell us that. Because you can make some clear sort of guidelines along that at a paddock scale at best, but once you start to try to apply that to the catchment scale there's just too much complexity in the landscape to provide that level of detail. I guess one of the key messages is that you need to understand the context of the particular catchment that you're working with. You cannot make any kind of blanket recommendations. So where the conceptual modelling comes in is understanding this is what the Bremer catchment, for example, this is how it functions. So then you can start to apply some sort of thinking around that. There is evidence that targeted interventions with revegetation in specific parts of a landscape can makes changes at the catchment scale, but you just can't broaden those recommendations out. 'There's a variety of tools. The one that we've developed within the wetlands program is called 'Walking the Catchment', which uses an approach with getting expert opinion from hydrographers. As well as talking to landholders who've seen flooding occur and building up those stories of how the flood has function in their area. So that's the conceptual model that we've been referring to. But there's also other models that you

	can, would be able to incorporate in this down the track, such as the HowLeaky type models which look at how ground cover intercepts rainfall and the amount of runoff that a certain level of ground cover reduces. But we're not at the stage of actually using that yet. 'Running the conceptual model itself is not a very expensive process, it's just the time to meet with the experts and the landholders and then one person to put that together. Having the time of the modeller, because there's not many people that know how to put that together. So it's more the limitation of expertise in conducting the work that's the problem.'
LG#3.2	'There's massive programs for … 'plant a million trees', it's just there's no coordination, that I'm aware of, that says and this is the area where it's most important for us to have a million trees this year.'
LG#3.1 LG#3.2	(**on catchment scale flood management mechanisms**) 'That's one of the good things the Reconstruction Authority has done here because they are a central agency that has the funding and the mandate to look across the state. They've been doing a lot of work in basins or catchments.' 'This idea of looking at entire river systems. It picks up all the tributaries and also has a look sometimes at even overland water, which is one of the issues in the flat country out in Western Queensland … because the land is so flat it just goes where it wants.' 'Many councils … reduce [flood studies] down to the three or four decent sized towns that they have within their boundary. They don't look at where the water came from or where it's going to go, the only interest is how's it impacting on this town and then the next town, even though it's the same water two days later in many instances. So it'd be nice to know what happens to it in-between times … legislatively, they're only responsible to their boundary.'
LG#3.1	'[The Local Government Association Queensland] has been actively encouraging councils to work with their neighbours on common issues such as we share the same river, or we're both below the same dam or those kind of principles, rather than just focusing on their own administrative boundaries; it's almost about recognising that we share this risk.'
LG#3.2	'One of the other tools that theoretically is available to us is a thing called a ROC, which is a Regional Organisation of Councils, where councils in a local geographic area may well talk. But once again they're based on communities of interest … there's no interest in redrawing those boundaries to pick up natural hazards. Riverine flooding's one of our major concerns – it's not the only one that we might want to use for delivering those new thinking boundaries.'
FM#3 (VIC)	'Flood studies are done town by town. So there is supposed to be an approach where you do a floodplain study first, into which you embed the flood studies. But that doesn't seem to work well actually because people just go straight to the flood studies for this town; "just tell us what to do with this town". Whereas what you should do is you should do a flood study for the whole valley and then into that you embed the local flood studies.'
LG#2	'Obviously our main dams above us … feed into the same catchment in the end. I mean every flood that we have had over the last two years has been different. We've had ones that were above a 1 in 100 in the rural areas for the creek systems. Those creek systems actually raised the river up to – if not a minor, to a moderate flood level … However, the localised rain events were actually more towards [the city] rather than up the catchment. We got flooded internally from the overland flows as well as the riverine flows because of what was being discharged from the dams themselves. If you were to take that kind of study and approach to try and implement things like [catchment scale flood studies], yeah it would be good.'

ER#1.1	(**on tailoring interventions to your landscape**) 'No two flood events are the same. However, the landscape will behave in a flood scenario in different ways, depending upon the physical characteristics of the landscape. So where the choke points are, what the elevation is and how fast the flood moves. What the flood channel looks like, whether it'll overtop or not. We've been doing a little bit of, I suppose, dynamic conceptual modelling to show what certain types of floods will do in certain landscapes. So it's really quite important. 'It's the creeks, the little creeks around Brisbane, that are the killers, because they concentrate and rise very quickly. If you're playing in them at the time or messing with them, they can become very dangerous very quickly and they're the ones where people will lose lives. So the function of the landscape is really quite critical. I suppose in two dimensions – one so you know what the landscape will do in certain extreme weather events, flood events. But second so that you know the intervention that you make. What effect that will have. 'Now in terms of intervention, you can only intervene to reinforce its resilience and natural function. So if it's about having deep rooted veg, or a mixture of deep root and shallow rooted veg along watercourses, then you can do that generally in watercourses that will rise and fall relatively quickly.'
ER#2	'Out west … the vegetation is very influential in shaping the floodwaters. So it adds to the spatial variability. Even grass can just divert the water to different parts of the floodplain because it's so flat.'
ER#1.1	(**on sediment movement during floods**) 'The Rivers Institute in Griffith University has been looking at what really happens in the watercourse with these flood events. Because some of the things that you think are happening aren't in fact happening. There can be a lot deposition as well as erosion. We haven't done as much work yet as we need on which fraction of the sediment is actually lost to the system. Basically washing out to Moreton Bay in that particular case. Because the mud patch in Moreton Bay is probably extended by 50% as a result of the Brisbane flood. A lot depends on which streams are flooding, if the Logan floods then Southern Brisbane – Moreton Bay catches it. If Brisbane floods it tends to be northern Moreton Bay. So they've been doing some science on the fluvial geomorphology of the system – to work out where losses are occurring. Which parts of the water course are suffering losses and which parts are getting deposition.'
ER#3	'If you're really serious about tackling this issue you need to do it on a big scale … to cut down the sediment force for Moreton Bay, you need to invest on a really big scale and you have to invest wisely because we know that 70% of the sediment comes from about 30% of the region. We know in those regions certain tributary streams are generating 70–80% of the load from that catchment. You can't just go in and disburse money and say "everyone should do riparian plantings". You've got to really prioritise it and target it.'
FM#1	(**on buybacks and compatible land use**) 'We've bought land [in the Lower Loddon], we've bought irrigation country, which is relatively intensively farmed and highly vulnerable to inundation. We bought those properties out, we're taking the irrigation infrastructure off them and we'll be repackaging them as much larger dryland properties. The purpose of that is very much to create a more resilient farming enterprise, farm businesses that can withstand the odd flood from time to time … If you're growing horticulture or irrigated dairy, it can be extremely vulnerable. That's what we found with that last flood. So dairy cows have to be milked twice a day in a special piece of milking infrastructure and therefore it's very much more location specific. Whereas

	grazing-type enterprises, if the flood comes, you can move your stock right out of the district if you wanted to. If your crop gets flooded, well so be it. People are generally attuned to crop losses on a fairly regular basis through drought or water logging or whatever, or bugs. So people's business, if you're in the cropping business, you're working on about one good event, one average event and one blouse out. But with dairy, you're looking at – you need to be operating on a fairly constant sort of a system. In this particular case, we had land inundated – significantly inundated for three months, which means the dairy herds were often on other people's places and it just didn't work. If you've got permanent trees, well they die after about – fruit trees, they die after about three or four days of inundation, through lack of oxygen in their root system. So they're not compatible either.'
EM#1	'Lower Loddon one is an example of floodplain restoration, so buying back that land and restoring the floodplain … a lot of our existing floodplain risk management guidance is focused towards urban areas in particular, rather than the rural environment, and we have more of a … local approach to community floodplain management rather than a reasonable strategic approach in some areas.'
ER#1.2	'In some cases land purchase and restoration would be appropriate. We're working with our state development colleagues on using, for example, the South-East Queensland Greenspace Network Plan to prioritise where perhaps important purchases could be made. Restore the landscape to a way that can be used for recreational values when it's not in flood, but can be used to store the floodwaters when required. So restoring a wetland where it can be accessed for bird watchers and recreational use.'
ER#1.1	'The primary consideration is to get people to live in the landscape in a way which is protective and resilient to severe weather events. It's not about taking land out and then managing it at public expense for the purpose of flood mitigation … when you look at Orleigh Park down in West End … there'd been houses all the way along where Orleigh Park is now. But because they were so flood damaged, all of that land was taken out of housing and turned into a public park. So the land use was changed to make the urban environment more resilient to flooding in the Brisbane River.'
FM#3	(**on education about the role of natural assets**) 'With all this stuff it's about education because people have such a woeful understanding of anything to do with floods and hydraulics and how they work. They all think they know how it works and often they don't.'
ER#3	'If we're going to really address this problem from an adaptation point of view, we've got to lift the general awareness of the public and also of our politicians about this because there's a very, very poor understanding about hydrology.'
ER#1.1	'Most of what's needed is – particularly at the local government level, supported by the state government and federal government – is to have a better understanding of what the landscape does in relation to severe weather events and the capacity to understand and work with the landscape. 'What we're looking to do with extension is to make sure people better understand the landscape they're living in but also to manage it. So that they can do their agriculture and live there, but it's managed in a way which is respectful of what nature's going to do with it in the event of an extreme weather event.'
ER#1.3	'Access to those historical channel maps was part of the community education tools that I came across. By showing people, "Look, it has been in this position before and it could well go back to that." So sort of helping them to understand how the rivers behave.'
ER#2	'I think that education and communication are really key now. So provision of information about risks and about ecosystem services – you know I think there should be more emphasis. People should be allowed to judge what they're losing by clearing an area to build a wall or armouring banks or putting in barrages, so everyone can be part of that kind of debate and that decision-making'

ER#3	'There's a whole range of approaches to educate local government, community groups. One of the ways I think would be really useful is developing visioning software and 3D simulations because it's very hard for people to see – very hard for people to visualise this sort of stuff. So there's some clever visualisation tools around now that I think would be really useful. It's also – we just need to spend some effort I think really pointing out – trying to dispel some of these myths because its – some of them are well and truly ingrained.'
ER#1.1	(**on recovery work and natural assets**) 'The work that's been done tends to have been a mixture of sort of engineering to reshape slopes and then replant … out of the Natural Disaster Relief and Reconstruction Fund … it was about $8.4 and $4 million invested in flood and cyclone recovery after the 2011 and Cyclone Yasi events. So that's been used for a range of on-ground works, particularly debris clean-up, but also some reconstruction work. Also some landscape assessment work using LiDAR which is a way of working out your sediment loss, or what's been eroded out of the landscape.'
ER#1.1	'[There] was an event up in an area around – a part of South Queensland called Mount Sylvia. There's a couple of little creeks there, Tenthill Creek was one of them and that was an area where the road up to the farms there weaves across and back, up the little watercourse. It was an area that got badly … inundated by flood, which destroyed a number of the crossings and it did quite a bit of damage to the riparian area. In order to get access into that area, a number of works were done with heavy machinery to effectively channelise parts of that watercourse and it caused a great deal of public concern. Criticism that the area had been overly engineered rather than necessarily managed in a way which is more sensitive to the environmental considerations. That criticism has variously been debated. 'Some of the work that was done has been to look at how best to manage circumstances like that. Because people needed to get access to their farms and get produce out and so forth, and also there were a number of existing creek crossings through there that needed to be reinstated. So it was sort of a focus area of whether an engineering solution is justified in the event of an emergency effectively, or whether or not there should be better plans for how to address these issues as they occur. Having better guidelines. The guidelines that we had were certainly used and implemented and people did what they did within the law. But the question is, are people happy with the outcome, and that's been the debate.'
ER#1.1	(**on the limitations of a catchment approach**) 'A sufficiently large event will overwhelm, no matter what you do. I guess what we've been saying is recognising that, then the capacity to use natural assets is in fact graduated from small events through to extreme events. So in terms of managing the small events and being able to limit the damage to the landscape by putting these – by looking after natural assets, that actually keeps the resilience in the landscape as much as possible. Recognising that in a sufficiently large event, no matter. 'It's a bit like a sea wall or a levee, in a sufficiently large event it's going to be overwhelmed. That's not to say that it won't handle sort of 80% of the situations that you need to manage.'
ER#2	'["Vegetation is useful for mitigating medium and small floods but is completely overcome by large floods"] When people say those kinds of things, they're sort of suggesting the hard engineering structures are going to be superior. But who's to say they wouldn't be overcome by the large floods as well? Then the risks associated with those kinds of systems becoming overcome are much greater than your risks associated with your natural ecosystem's failing.'

INS#2	(**barriers to a catchment approach**) 'Local governments being perhaps a bit over burdened … I think expectations are pretty high. Quite often, they might not be the best equipped, not just resource wise but I think it came out of Queensland Flood Commission that often the flood mapping can be better done at a basin level or a catchment level, rather than the artificial borders. 'This whole area needs a greater investment of money from all, like state and federal governments. I think that's pretty clear and the insurance industry has been pretty strong on that. But also just more support in the sense of – physical support as well … Giving them that leadership to say, yes, we want you to do this and we are going to go in to bat for you.'
INS#1	'I think where mitigation can be planned and implemented that has additional benefits, particularly ecological benefits, that should absolutely be looked at. But often these local councils are really having to work hard just to get minimum funding to bulldoze an earth bank around their town. So getting them to create a new ecological system and wetland further upstream is – that's an order of magnitude more difficult than what we're trying to do now.'
UT#1	'We're not very good … to get systems thinking on these problems. We tend to see it as a flood problem in this town. Well that's a consequence of a series of actions that might have occurred upstream. I'm not sure that we're very good at looking that … if we look at the Brisbane floods, … the Brisbane River's actually shallower than it was 50 years ago because they've actually silted it up a bit. So in fact that … raises your flood height. Why is it silting up? Well that's because of our land use upstream. So all these factors influence these events, but they're not very well understood. I think it's about seeing rivers as a system, as a living system rather than this one little element that comes past the town.'

5.4.13 Flood warnings and response

EM#1	'I really see that emergency services are going to find themselves on the front line of a lot of the climate change scenarios.'
EM#1	'When it comes to the residual risk, that's obviously going to really need a lot more focus on education of people and better warning systems and better emergency plans for the future. 'In terms of future investment and future policy change, I see the ability to focus resources more in improving flash flood warning systems as a really critical thing. [The BoM Review is] saying that they need to investigate what the best model for delivery of flash flood warning services is. There's a policy there by the bureau which says that they don't do flood warnings for anything less than six hours. We saw in Queensland, and we saw in Victoria that a lot of the damage that was caused and particularly where a lot of lives were lost in Queensland were these flash flood environments.'
EM#2	'With Cyclone Yasi, when they declared and put evacuation orders in place for Mission Point … people refused to go … when the cyclone struck people were all panicking and saying, "We need rescuing." "Well sorry, we're not going out in the middle of the cyclone direct to you. It's a category five cyclone." We had the audacity of people saying, "No one told us it was category five … we didn't know what our risks were." Well, we actually gave the risk, "if you stay here, you could die." So there is a lot of expectation so maybe we [need] more education. 'People have their responsibility for their own safety … I heard complaints the SES didn't come and do these things for us, no one knew, we had to rely on local community people to pull together … I said, "Who do you think the SES are?" – then, yeah, that's what you need to be doing when you live in your more isolated areas.'
LG#1	(**on the importance of improved modelling for flat landscapes**) 'We need a greater level of monitoring on some of these anabranches which are typically, in

	a normal year, actually quite dry. The internet has been fantastic, I've got to say. If we can utilise some of that information, that modelling, if we can get a few more stations in along the water course, along the anabranches to give use a good idea of the modelling, that's fantastic. LiDAR mapping, the survey mapping from satellites … particularly in that part of the world because it's so flat … [to know] what the flood's going to do.' 'A strong wind from the east or the west can determine which way the flood water will go in this flat country … you're talking about water that's essentially probably only a foot deep in some cases but across a large flood plain wind can have an effect if it's pushing the water over a little bit and crops. If a farmer which ties into land use, depend on the time of year where a paddock has been stripped of its wheat crop or whether it's at a stage when the crop is thick, essentially it's thatched wall of crop, that can push water – and the neighbour on the other side of the stream, has got a paddock essentially bare. So land use and farming practices which once again is going to be very hard to model but that also has an impact on the flat topography up here.'
LG#1	'You've got to be prepared for IT to fall down and have that backup plan and that would be one of my concerns … I can actually function without a computer. But there are numerous people who I've seen these days that they really need the IT around them because they just can't function without it.'

5.4.14 Community resilience

EM#3	(**what is community resilience?**) 'Community resilience is … really about giving them timely and accurate information across all the different timelines – so that's in our planning, our mitigation, our response, our relief and recovery phases – access to information where they can make informed choices.'
LG#3.2 LG#3.1	They understand cyclones occur, their house is prepared, they have an emergency kit ready to go, they've thought through all of the scenarios, they know their neighbours. Genuine community understanding versus community information. Knowing where you are and the environment you're in and being prepared for it, that step beyond information. Awareness doesn't actually equal behaviour change. Emergency Management Australia attempted a whole lot to understand how to do our community education campaigns better and actually build that resilience at the local level. Going that step beyond, that's a line on the map.
ER#3	'[Community resilience] is part of the awareness thing. It's also … getting a better understanding of what needs to be done in terms of allowing paths or mechanisms for people to evacuate areas easily … making sure that services can get in and out.'
INS#1	(**on risk awareness**) 'A lot of mitigation can be done locally by the property owner if they're aware of the risk, and that seems to be the thing that's letting down most communities is people are unaware, either by choice or because they haven't been informed of what their risk is.'
LG#2 (NSW)	'Community awareness I think, you know, you can do that from your development controls. Obviously developers would be aware of what area they're going to be building on. But it's later on when they're selling the blocks and selling the houses and things like that. Usually the first owner of a house would understand that yes, they're built on a floodplain. Whereas a purchaser afterwards would not. So it would be a matter of identifying those types of things on a Section 149 or 88B type of identification for each property. So when a purchaser goes through with their solicitor and identifies a property for purchase, those things need to be raised at that stage.'
FM#1 (VIC)	'If these people choose not to participate [in the voluntary land buyback scheme], then that's their democratic right. But into the future, there are enough words on titles now, in that area … We can't stop you doing what you [want] when these properties change hands. All we can do is make you aware through various warnings on the title, when

	people do their conveyancing, that they need to think about these properties in the context of their farm business, aspirations and to approach with care and put a high risk value on these lands.'
LG#1 (VIC)	'One thing that I think will be very important will be the FloodSafe Program. That's something that I would really encourage, certainly for the ministers to get behind and put money … But informing the community that, "Hello you have bought into a floodplain, please be advised that this is the height of your floor." Everything being in Australian height datum, I think that's also important … So that people have a good understanding of where they live, what their impacts are … when people are potentially buying a property, they actually know that when they open the meter box that inside the meter box is, "Your floor height is this, you're in this type of flood zone", you know. I don't think real estate agents or potential property sellers would like that.'
ER#1.1	'Globally we're seeing intense events far more frequently … what we're going to see is a greater cultural awareness of the implications of climate change. Whether it's managing heatwaves, managing fire, wildfire, managing floods and cyclones and so forth … So I think we'll start to see the culture changing as these things affect more and more people personally. Particularly as the cost of dealing with the destruction affects insurance, but also affects people in terms of their personal recovery. People are going to want to better understand because they'll need to deal with expense and hazard and danger.'
ER#2	'The only thing you really can do to increase social resilience is by improving networks … education and providing information is a really good way to educate and communicate the risk but also to build those networks at the same time … so just providing any information. I think a lot of the information that's provided publicly is just at a very big scale. It's hard for people to relate to their own areas.'
ER#2	'Having those signs out and things like that around the place to show flood levels … a few more signs would be healthy.'
INS#1	**(on language to convey risk)** 'If I say to somebody you've got a 1 in 100 year risk of flooding of course most people will just go oh well, that's great, it flooded last year, I've got 99 years up my sleeve, no need to worry about it. So the language needs to change and that's something that we all need to do, so we need to be able to say to somebody you've got a 1% chance of flooding in any year; if you own this home for 30 years, you've got a 30% chance that it's going to flood sometime in there. That suddenly creates an entirely different risk picture the person has. 'From that understanding you will then get greater activity in terms of adaptation at a local level. So they may decide that okay, at some point I am going to elevate the house when I renovate it, or I am going to seek out and take out flood insurance because this could happen.'
INS#1	(**on enabling mitigation**) '[If you improve awareness of risk], you then get community buy-ins around larger mitigation projects and that might be better stormwater infrastructure in the local area to carry floodwater away or localised flood gating, or it could be greater understanding in the community that the local council needs to raise $10 million over the next two years to pay for a flood levee on the edge of town. So once you've got an understanding of the risk in the community you then have greater buy-in about I now understand why the rates are going up and so you'll get a community push towards mitigating the proper way. Rather than the sort of arguments that we see going on now about oh well, I shouldn't pay it, the extra rates because only the people by the river will benefit. If people actually understand how bad flooding can get they'll contribute.'

INS#2	'There is a bit of information out there about what you can do. It's kind of various websites and brochures. But I also think there is this kind of collective head in the sand thing in Australia, that people just don't seem to think it's a big deal … I just don't think people kind of take it seriously enough … maybe if I was living in an area with that risk of flooding on a frequent basis, maybe I might have a different attitude.'
INS#2	(**on individuals taking responsibility**) '[People are] building their houses in certain areas that are open to flood risk, or another risk, and then expecting all the help in the world when something happens, or being annoyed that nobody told you that there was the risk. So informing yourself and taking responsibility for yourself … you can't just step back and say, oh well, it's the community, individual responsibility … that's part of the national strategy about all parts of the community – government, businesses and individuals – taking responsibility for understanding the risk and then what you need to do to avoid, prevent or negate the risk.'
UT#1	'First there is actually getting them to believe they have a responsibility. Then they need to understand what they can do and what the consequences are of not doing things … we've got a huge education issue there. It's very hard to educate somebody about a non-frequent risk and a risk they don't perceive applies to them … the only time it's worth doing flood education is in the three months after a flood event because after that people lose interest again.'
EM#2	'City people are far less resilient … We've had a lot of people, there's been a move and change in the population base. So people who grew up in North Queensland knew what a cyclone was, knew what to do in a cyclone and the regular event which had occurred … but we've had big population change and people have moved into those areas and they've expected city-based services …'
FM#1 (VIC)	'There was a whole expectation that the government was going to do a fair bit for them. I think initially they were of the view that the government would come in and compensate them for their losses and build something which was going to ensure that there would never be a flood in that area again. Neither of those things were going to happen and I think it's only starting to dawn on a lot of people that they need to get on with life and make their own decisions about future flood risk.'
EM#3	(**on individual capacity to implement resilience**) 'Low socio-economic households in rural areas … some of them actually don't have the resources to hand or the capacity to do much about it … they don't actually have any savings or capacity to invest in any levees or putting the house up higher on stilts, but they can make the choice about whether they stay or go when faced with an imminent risk … having an emergency kit which all agencies advocate … it gives them a little bit more information [so] you have some sort of key strategies or plans.'
INS#2	'The other issue is, even if you do know what to do, do you have the facilities to do it. So you talk about putting various things in a higher level but if you've got a one-storey house and it floods …'
UT#1	(**on applying experiences of other sectors to flood education**) '[In] Victoria, they've realised that all the money they spent on health education has been a complete waste of money because people don't listen anyway. They've done a program where they went to companies and said, "Tell you what. We'll come and do wellness programs for your staff about things like diabetes and about obesity and heart disease. But you pay half and we'll pay half and do it during their work time." "Oh yes, we'll do that." So that attracted the audience who actually had time to listen because they were being paid to listen.'
EM#3	(**on implementing community resilience**) 'We're looking at a joined up, integrated approach with other agencies that were in communities where we know there's more than one hazard. So they might have both a bushfire and a flood and another type of hazard that they're at risk for, so all agencies

	actually going in together and working with them collectively, rather than working in isolation and you know everybody bombarding the community so they're not quite sure what they should be doing for what incident.'
EM#3	'It's actually using existing networks and it's really about raising community awareness about the hazards that they may face and what the impact of those hazards will be to them … it needs to actually be able to have the continued support of community members to actually sit on that group as an ongoing commitment … the same person is doing multiple roles, depending on the size of the community … we're relying on the goodwill of individuals to actually step up and take on some responsibility but … it's about shared responsibility and not imposing what we think is good policy of standards.'
EM#3 (VIC)	'Very often … it's left to local government to try and get everybody's buy-in from the different agencies to get their [flood] plans in place. So we've spun that around and said well we're the lead agency for flood so we'll lead the process to get you a local flood plan. We'll bring all the local knowledge into the same room and then we'll work on that together. So council, local catchment management, community members. 'It's done on a specific footprint. So it may be a community or it may be, in a rural area, a stretch of road that by all accounts to them is their community. It may be a municipal footprint or a township footprint or a catchment footprint … [goes] through a risk assessment process … stakeholders identify a particular footprint.'
EM#1 (VIC)	'Through the recovery process, they've engaged various building groups to improve the way that people have rebuilt – for example, not using certain building materials, etc. when building to improve the resilience of their house and contents or business into the future.'
FM#3	(**on why people try to lay blame after a flood**) 'It's partly about justifying continuing bad practice. So a lot of people want to identify some simple mistake that people made … when in fact that's very seldom the case. Most often it's complicated problems and they want somebody to blame so that they can persist in doing what everybody knows is stupid … we haven't had any floods much in Western Victoria for years. We've let all the planning regulations go, people can build wherever they like, even though everyone knows it's a stupid place to build, but it's an irresistible urge for councils so they allowed it. The floods come along and then they start to blame whoever they can really to deflect attention away from the fact that it was just a major planning – sort of a generational planning failure that everybody's complicit in. But they immediately turn to simple explanations like, the dam wasn't regulated properly … Or if we just cleaned a couple of twigs out of the stream it wouldn't have happened.'

5.4.15 Insurance

INS#1	(**on insurance affordability, availability**) 'Emerald and Roma are both locations that have flooded three or four times every year for the last four or five years, so it's little wonder that insurance starts to become untenable in those locations.'
UT#1	'Australians have one of the lowest rates of insurance in the Western world … They've done the research to [be able to] say that we can't actually pay for it. Then it turned out, when they did the Queensland research, people spend more on alcohol and gambling than the cost their insurance would actually have been. But that's more important to them because someone's going to bail them out [if they get flooded] … what they did is make a lifestyle choice to say, well I'd rather gamble and have alcohol than have a house repair after a flood again because it may not ever happen. But I know I'll have a high from the gambling straight away. So actually that was a personal choice … a lot of the issues around flooding come down to really basic cultural issues.'

UT#1	'Australia has had such a bad run the last few years. There's the whole discussion about will they ever insure within Australia? Because we've actually been a net drain on the global insurance market.'
EM#2	'The insurance market in Australia is very different to, say, the insurance market in the United Kingdom, where flood is offered and there's a lot of flood but there's also a larger market and a larger pool so they don't seem to have the same high premiums.'
INS#3	(**on pricing flood insurance**) 'If a house is built in a floodplain [and the] river floods every 20 or so years … to rebuild your house, because every 20 years it goes under, it costs us $200 000 … to recoup the 1 in 20-year flood event, we've got to charge that … So it's $200 000 divided by 20 years … that's $10 000. Now, if I want to cover a 1 in 50-year event, 1 in 100-year event, not just 1 in 20, I might add another $2000, $3000, $4000 on top of that. So there's a legitimate rebuild cost. The long-term average cost for that risk is about $14 000. Just for the flood component. You then add $1000 for all the other bits. The theft and the liability, bushfire and all the other components of that premium. So you're up to around $15 000. You then add staff duty, which is another 10%. That's $1500. So after $16 500, you add another 10 per cent for GST. You're up to, now, $18 000. Then in NSW and Victoria, you add another 30% or 35% on top of that for fire services levy. So insurance is taxed somewhere around 50% in NSW and Victoria. Although Victoria is abolishing it. So, very quickly, your premium is up at the $25 000, $30 000 mark. Now, is it legitimate that we charge their customers $30 000? Or should we only charge them $3000? Of course, we charge them $3000. I need to find another $27 000 from other customers. So I'm saying to that customer, "Hey. You don't want to pay $30 000, it's too much, but on your policy we're minus $27 000. So we need to cross-subsidise and … find 27 other customers prepared to pay an extra $1000 … suddenly, we're uncompetitive.
INS#1	**(on opportunities for new insurance products that might be applicable for climate change)** 'Gradual sea level rise … or tidal flooding … [are] not covered by virtually all policies. [It's] under this general banner of actions of the sea, and that's probably something we need to start examining over the next decade – how might we start to offer that? It's a very, very different style of risk, of course … That gradual loss of amenity of your land and loss of value in your land due to encroachment of the sea, if it is a slow, slow death of the value of your property, at the moment you can't insure for that. So it's got probably a closer analogy to a life insurance product where you might amortise the loss over a number of years and your policy will mature in 30 years' time. But currently there is no policy globally that works like that, for property.'
INS#2	'I think it's more about making them affordable. So kind of – perhaps, at the moment being a bit unimaginative in presenting products in one kind of a lump. So whether or not you can make them a bit more mix and match, and moveable pieces, rather than providing a new product for a new type of peril, if you get what I mean. So it's more about making them more flexible to take bits in and out. I think that's where it will probably move to.'
INS#3	'You could cover actions of the sea, couldn't you? I suspect that there's a market out there which is a catastrophe product. So rather than being covered for – if the burglar comes and steals something off you or a small breakage, there's probably a market opportunity if they just cover me for catastrophes, you know? My house burns down, my roof gets a hailstorm, a cyclone, my house burns down in a bushfire. You might call it a cat cover, you know? A catastrophe cover. I suspect there's an opportunity there. Particularly if global warming gets worse, you get more furious storms and more severe bushfires and more severe cyclones.'

INS#2	(**on insurance providing incentives to mitigate**) 'Obviously, we've been lobbying pretty hard on the mitigation issues and around planning. Whether or not you want to go to the brinkmanship of refusing covering some areas [referring to Suncorp's decision not to insure Emerald and Roma unless mitigation measures were put in place] … But I can see that it is kind of a pretty bold move. It places a lot of pressure on those councils and the state government.' We've been thinking as a business, in doing rebuilds, about how we can provide an assessment of the damage and say, okay, these are the things you could do to improve your resilience to the house, that would only cost a little bit extra or would cost the same. We're going to make those changes in the rebuild. Then there's a list of things that would cost the customer more money and give them the option of taking those steps … So basically doing the work for them in assessing the things they could do. Doing the things that aren't going to cost us any extra money and then giving the customer the opportunity to choose to do the things that will cost them a bit more but are going to end up reducing their premium because their house is better protected. [It would imply control of the rebuild by the insurer.] It would also imply some expertise on behalf of our suppliers or on behalf of our assessors … these are just kind of ideas at this stage. But we do probably need to be more proactive in that area and I think, for too long, insurance companies have just been more than willing to whinge at the government about not doing anything but, in their own business models, not taking any steps to – just replacing like for like, or just handing over a settlement to the insured and not really caring what happens next.'
INS#3	'Insurance is about covering the unexpected. It isn't about covering the expected. 'Our job is to cover you after an event … it's an individual's responsibility and the government's responsibility to mitigate or stop the event from happening. The mayor did say, "Well, you poured $100 million into our town, why don't you pour another $10 million and build up the levee?' But I think that's fundamentally, not what insurance is about … I think the insurance industry should talk to customers about their flood risk and any information that they need to be able to make an informed decision, but not build levees for the whole country.'

5.4.16 Which measures are most cost-effective

INS#1	(**on structural mitigation measures such as levees and flood gates**) 'By and large, flood mitigation is not rocket science but it can be very, very expensive to plan and implement because often we've constructed right up to the water line in these places … it does require convincing some members of the community that they're probably going to have to have a flood levee built in the backyard.'
INS#3	'In Emerald, some of the fences that were around properties were actually levees. So rather than putting their fence around their house, it was actually a flood levee … it's like a Colorbond fence … they just pump out the water that comes underneath the fence.'
FM#2	'These towns which are actually now going to be more regularly flooded – you know it's probably going to be cost-effective to have levees around them rather than rebuild the houses or move the towns. So it think levees are inevitable at this point because of the sunk cost of those houses and the increasing risk over time … Roma … maybe not so much Emerald, but St George … Because it's a big wide brown land, a lot of extra rain may only increase the flood event by a small amount … So it might only mean a relatively small increase in the levee in, say, St George, to dramatically reduce the flood – take you out to a 1 in 5000.'

LG#2	'We actually have about 17 km of levee classified under our assets … 99% of our levees are urban based so we have potentially a lot of cost associated with investigating, reviewing and maintaining. Obviously you have to have vegetation on there to also hold and protect and levee itself. So there's those types of daily requirements. 'Then, in an event and after an event, they do tend to have a lot of scouring and sloughing and things like that as well. So a small fix is an expensive fix. Basically if you are to have damage in one particular location, it might only be a metre wide, you would tend to have to probably pull out five to 10 m worth of the levee to actually reinstate it properly.'
FM#1	'[To install a ring levee] it's about $25 000 a dwelling to move the dirt in and pack it down and build it to an engineering standard. So if you're looking at a reasonably solid house on a floodplain, you're not going to get insurance for it – the insurance companies just won't insure houses against flood if it's in those areas. So I would've thought 25 grand's not a bad investment for people to do themselves. 'We've done it in the highest risk areas out of courtesy using the taxpayers' money … We put a section 173 agreement on these levees that we've built, which … does two things: it indemnifies the state against the levees falling over into the future. It obligates the landowner to look after them in a way that ensures that they'll operate properly.'
INS#2	(**on housing affordability: long term vs short term**) 'In Australia, there's been a very short-term view of [housing] affordability. But when you think about North Wagga as an example, where people have built a long time ago, it floods nearly every 15 years or something. The number of times they've had to rebuild those houses … you might save a bit of money purchasing that land and building a house in the first place but the cost to the community and the government and insurance companies, and the residents themselves, over a 50-year period – is that [initial] saving really worth it?'
EM#2	'There's competing priorities there. We want affordable housing. We don't want to change our urban footprint so we want to be nice and green and environmental … So we've designated what the urban footprint is and where places could expand. So that means really good real estate is expensive, and so if you're looking at affordable housing and affordable real estate then one of the ways is you look at cheaper land. [Then] the pressure is on how they actually release land and the more caveats you put on in relation to that land – how it can be used, and what sort of nature and type of building needs to be built there, say to make it flood resistant in particular, then suddenly the cost of that housing goes up significantly. So you've overcome your policy objective of wanting to get low-cost housing or affordable housing.'
INS#2	(**on building codes, materials, design, planning**) 'There's some stuff we've been looking at around building codes and encouraging flood-compatible materials, in new buildings. Existing buildings are a bit more difficult … the National Construction Codes just released [include] certain provisions around building for flood-prone areas. It's mainly about the floor height … they also make an assessment on how much more it would cost to build a house in a more flood compatible way, as opposed to just building a house in the normal way. It's actually not that much more expensive…and then when you also contrast it against the costs the government and the community of rebuilding those conventional houses. So if you do the cost comparison there. But there are actually some low cost alternative materials that can be used. So I think the building code stuff is probably a pretty good area, encouraging different ways of building. In a lot of ways, going back to the old ways of building with the Queenslanders.'

INS#3	'You can put your house on stilts … if you think about the traditional architecture of a Queenslander. It doesn't really matter if your stilts are going to be wet.'
UT#1	'There has to be a decision made by government, or by who actually owns the instrumentality … that mitigation in design is a valuable way to spend your money. So what we're seeing at the moment, in the last 10 years, is rapid modification of assets to mitigate disaster risk, when actually it would have been cheaper to have done it when they built the thing. So we, for example, installed generator connections points on all of our sewage pumping stations. So when there's no power, like in a flood, you can actually run the generators. They should have been built like that. Actually retrofitting has cost far more than building it into something at the start.' 'If you're building to least-cost, short-visionary thinking, you design all that stuff out because that's extra cost. If you're actually going to be running the asset for 20, 30, 40 years or more, it's important. If you expect it's going to be 100 years, [you'll] probably use that in the long term … the importance of building a resilience capability into long term infrastructure.'
LG#2	'[Measures such as raising houses] would be expensive. However, insurance and things like that, I know in our area that it's increased for a lot of people. So that's an annual fee of – I don't know, I think it's anywhere in between $2500 to $6000 at the moment. So that's up to the owner, I suppose, whether they think that their current location is worth spending that amount of money.'
FM#2	'Planning is really the least cost.'
LG#2	'Definitely, planning. Better planning.'
FM#3	'In areas where there isn't a flood overlay, [flood zoning is] the local government's responsibility. So there's constantly compensation and stuff going on because of mistakes.'
UT#1	(**on floodplain restoration**) 'They did a study on the Mississippi, based on restoring wetlands up the top of the Mississippi and the impact it had on flooding down the bottom of the Mississippi. They claimed that the flood plain restoration costs were far less than the flood costs.'
ER#3	'Through the Healthy Waterways Partnership, [we've] worked on understanding where the sediment comes from, what causes it. So there's been very detailed work prioritising which catchments, which sub-catchments within each, how much of the network would need to be targeted. We've done full costings. A lot would need to be done, have a spatial prioritisation decision support that would allow people to say why one area's better than another. Our estimates are that for South-East Queensland, Moreton Bay, for $500 million you could halve the diffuse load – the sediment and nutrients to the Bay … a resource economist has done the actual full business case for that. It's a document called 'Saving our Bay' and it's with state Cabinet now. 'Costings on it are looking at the value that there is [for] the waterways downstream. So two things are being looked at in terms of drinking water supply. So one of them is we know that with the loads of sediment going into our water storages – with the volume of sediment, what that means in terms of lost storage and how much that water is worth annually. So we can put a dollar value on the loss of water supply because the dams are silting up. So those numbers are known. We also know that every time you get a flood event, or even a moderate flow event, down these degraded catchments that the cost of water treatment goes up. So we know what the additional cost is for poor water quality and that cost is passed on through water treatment charges. So they're two of the ones. 'It makes sense to invest more in this kind of work as a first-barrier treatment for improving water quality than it is to build another water treatment plant. I suspect that

	when you look at the sums of it, it's probably more value for money to address these sorts of issues than it is to try and engineer your way out. 'Then we've got the avoided costs of damage to sea grass habitat – the value of the recreational fisheries, the value of the commercial fishery, tourism value; all associated with clean water downstream … In terms of property damage I don't think anyone's really got the numbers on … "had we had this stuff in place how much farmland loss would have been avoided?" I think we've probably got the ability to do that as well.'
EM#3	(**on flood awareness**) 'The more that we can mitigate or provide risk reduction strategies prior to an event occurring, the less cost it is across the whole spectrum … for instance, provision of really good information about … how you might put a levee in or you might sand bag your property or you might move all your furniture up, that would actually mitigate the impacts on your household which then saves you the cost of actually having to re-build or replace … really good risk planning and mitigation and reduction strategies in the planning phase absolutely reduces the impact cost in recovery. It could be quite cost-effective in that it's just developing fact sheets – we have our local flood safe guides at the moment … or you can run some community workshops that then incorporate venue and catering type costs to whole school packages where you have to pay for a facilitation kit and the whole works or whatever the case may be … [a full scale package] without including salary costs – $80 000 maybe … across two or three [communities].'
LG#3.1	(**on prevention versus damage costs**) '[A COAG report] suggests that a dollar invested in mitigation saves about $2.40 or something ridiculous I think in response and recovery costs. Whereas the bulk of the research is more in the area of $1 spent before the event can save you $5–$7 in costs afterwards. I guess the bridge example that I used earlier is a good case in point. That if you're not cleaning the bridge, inspection the bridge and worst case repairing the bridge every X but now it's every X plus five, then that's going to save you money in the long term … So that's where we look at the value of betterment rather than "it's an extra per cent on a project".
FM#2	'That would be a market failure in any other circumstance or an inefficient allocation of government resources … it's that classic "least up front cost" … not taking account of the long-run cost of having to replace it again next time.'
FM#2	(**on relocation vs repair of existing properties**) 'If this happens once every 35 years, is that a risk people are prepared to live with or adapt to? These people have stayed where they were – most of them. They've taken the flood event and then gone back to their leafy, riverside properties. Where you've got such huge sunk costs, if you've spent – if there's a $500 000 property or $600 000 property. If it's $35 000 every 35 years to repair it – or $100 000 every 35 years – it's probably cost-effective to take the hit. It's more cost-effective to take the risk and even wear the damage than it is to abandon.'
FM#2	One of the things that's come out of the Reconstruction Authority, which is quite good with its project, is that you don't need a one size fits all flood study. There are some relatively cheap and effective studies for where there are low development pressures … One's a $15 000 study which tells you, "We don't build in this area; we do build in that area" … and $300 000 to $400 000 for a regional provincial town, so it's a significantly different cost … the level of precision we need to have in those contexts is reasonably low because we're not talking about a lot of developments – maybe $3 million [for Brisbane].'

5.4.17 Professional training

UT#1	One of the risks with engineering courses is they don't always teach history. The solution is, to most of these events that come, well what did we do in 1922? Because when the modern infrastructure fails, [people are] not resorting to how we did things 150–160 years ago. So it's important that we actually retain a historical knowledge of what was instituted in past history. So I think that that's a risk that that's being lost with the younger workers. A good example is in Christchurch, where they dug pit toilets and where they first off just discharged sewerage to rivers and then they had pit toilets in backyards, then they had portaloos … the style of approach is like going back through history and actually upgrading the historical approach to the modern solution.
UT#1	We need to be developing, as part of our engineers' and designers' training … education about hazard mitigation in the design of assets, which isn't in their courses. That's all hazards, so the bushfire, flood, wherever it might be … if you're going to actually start to teach that when you design an asset you should consider the asset risk for natural hazards, well first we need to have the data on the natural hazard risks … we don't have a national flood mapping system.
FM#3	'There's not really many courses … the people who work in flood management … they're usually engineers, whereas the floodplain managers tend to be natural resource managers of different persuasions. The whole area of floodplain management is … fraught with misunderstandings about what that job is and all that sort of stuff. But I guess it's not the sort of thing that you do too many courses on. Traditionally it's been in the engineering area.'
ER#3	'You could get both undergraduate and postgraduate training in looking at things like flood risk and the engineering side of things. So I suspect that most of the courses available on floodplains and flooding would be from an engineering perspective. In terms of the natural side of things – the importance of river floodplain connections – maybe a little bit in some of the universities. We run courses in riparian and riparian management in environmental water so we pick up a little bit of it but nothing ... other than what would be picked up in maybe some geomorphology, river geomorphology, undergraduate training, and probably most of it would be engineering and hydrology.'

5.4.18 Research needs

UT#1	the issue will be … places like Wollongong and the South Coast, where with very high rainfall intensities, they're more flash flood areas … They're the flooding we have least understanding of, which are our flash flood areas. The standard riverine, river rise flooding, we've got reasonable knowledge of, reasonable mapping for, reasonable ability to predict what's going to happen there. I'm not sure that's our big problem from climate change. I think our big problem from climate change is probably flood risk associated with Wollongong, Northern Beaches, those areas impacted by flash flooding events. Probably little rivers like the Cooks River, that really – people don't pay much attention to, but are really subject to flash flood rise.
UT#1	'There's heaps of research on how people perceive risk – we know how people think about risk. We know how to educate someone e to buy something because the big sales companies spend millions understanding that. What we've never done … is applied all that research to emergency management education. 'I think we've got to move away from the random model of education, deployed by emergency services in their isolated budget areas with uninformed, uneducated clues for how to go about it. Get a more professional approach. We need to engage things like marketing companies, etc. to really think it through as to what the right solutions are. Then run trials, research test those trials.'

EM#1	'There needs to actually be a bit more research in terms of the tolerability of flood risk. We talk about the 1%, we talk about different levels of probability. They're just probability, they're not a reflection on risk. So we need to be basing our decisions about flood planning management on the levels of risk that people will be facing for the development into the future. We don't necessarily have a great knowledge base or research basis on which to draw what is tolerable flood risk.'
FM#1	'I think it's really important we review our learnings about flood management and do things better into the future. So that's irrespective of climate change overlay.'
FM#2	'[To achieve betterment] you have to establish the cost-effectiveness and the higher expenditure that would happen … Are we doing enough research on the sorts of pavements that are resistant to flooding? What's the marginal cost of investments in roads to make them able to stand those sorts of flood events and more frequent flood events, and is that indicated on the frequency? You can do a reasonable economic analysis of what are our break even points. What's our internal rate of return on the marginal cost of investing in more resilience? Are we making least cost investments or are we just building least cost up front and paying for it again and again and again by having it wash away all the time? … We'll need some case studies and some trials of different types of pavement.'
FM#3	'Research has to be timely. You just imagine you've just finished a big flood strategy and you've just done all the thinking about it, had all the inquiries and suddenly some academics come out, three years after the event, with a bunch of suggestions. Well, too late. What are you going to do? Are you going to say, "Gee we really stuffed up with all of that policy stuff. We'll just have to wait and redo it all"? They're going to defend their policy and they're going to implement it because it takes years to get it all up.'
ER#2	A lot of managers think of riparian vegetation and floodplains vegetation as actually spreading flood risk and worsening flood damage. I guess my assumption is that through rapid transpiration and there are sink areas [vegetation would] use the water and hold the water … I'm not aware of any studies that have looked in more populated areas about the pros and cons of the riparian vegetation. Obviously there are lots of assumptions on both sides. So as ecologists we assume, the vegetation is good. Then you hear from a lot of managers or landholders that oh, they don't want the vegetation there because it slows the floodwaters down and pushes them out into the floodplain. But I don't think either perspective has been tested.
ER#2	'[Adaptation] requires a lot of information … about projected changes but information about values as well. I think that we mustn't shift all of the emphasis onto one side and that we must make sure that adaptation is a really participatory process and that all members of the community have an opportunity to be involved.'

5.4.19 The types of measures or approaches to avoid (Question 4b)

UT#1	(**on disaster recovery funding**) 'Government being the grandmother … it encourages people to take more risk because we're going to bail them out. 'I'm not convinced that giving Queensland $5 billion will do anything about changing Queensland's attitude to building on flood plains … I think that's just going to encourage continued building by Queensland – which was, I have to say, one of the nation's worst states for building on flood plains. We'll be giving another $5 billion next time I guess because I'm not sure there's any learning.'

UT#1	'I just can't see … there's been any attempt to prohibit rebuilding in the worst affected areas. So we'll waste money again.'
FM#1	'You can't just keep going in there, providing aid, patching people up and patting them on the head and letting them go away to do the same silly things again. You've got to get some sort of lasting change.'
LG#1	'We're replacing like for like … and I think that was very short-sighted on their behalf because I know people replaced structures three times after November and then again after January and they were just replacing like for like whereas if they'd fixed it correctly the first time with a new improved version or betterment …'
EM#2	'"You've got to look after yourself." We don't tell people that. We give people the expectation that the government's going to be there and come and help them out and come and rescue them.'
LG#3.1	'The same authorities that tell them that they need to be prepared and need to be resilient are the ones that are knocking on their door, sometimes before the rain even stops, saying here's a handout, go and buy yourselves some new stuff … there's a learned helplessness rather than a learned resilience in the system generally. But certainly after disasters, everybody is sitting around looking for help … One of the hardest bullets to bite, I reckon, is the one that says we convince the government to hold back some of the things that it can do.'
LG#2 (NSW)	'After an event sometimes we're looking at a full reconstruction. So we put in a flood claim, there's two different types of claims that we go through. One's through RMS from the RTA for roads and then there's another one – the Department of Commerce I think it is, the RAA, something like that is the next flood claim. That's reviewed by Public Works Department. So the restrictions on what you put in those claims mean that you're reinstating what was existing. So resilience probably should be played in a larger part into those flood claims. Because like we've seen over the last two years, we've gone back and redone things two or three times … we've had one road that had to be reconstructed three times at a cost of $1 million each time. There's $3 million that could have been put towards building something that was more resilient, rather than the $1 million quick fix.'
FM#2	'Transport road builders at the beginning of the project were deeply concerned that all they were being allowed to do was build it back and it'll just get washed away again and we could do it better for a little bit extra. This doesn't make sense.'
EM#2	(**on flood insurance**) The National Disaster Insurance Review and the proposals that came out of the recommendations … If we mandate [that insurance premiums include] compulsory [flood] insurance … your house insurance might go from $1000 a year to $15 000 or $16 000 a year if you're in a prone area … So you take out no insurance and you're not covered for any risks at all. You're not covered for storm, you're not covered for the furniture, you're not covered for anything like that. So actually, it would have actually had a perverse effect of being a – it would have actually have resulted in more people being uninsured for more risks than not being insured for the flood threat.
EM#3	(**on perceptions of safety and levees**) 'In the township of Nathalia earlier this year, in March … the community had put a temporary levee in place and it was almost a carnival atmosphere behind the levee that was almost topping and kept being compromised. Perceptions were that the levee would hold, but if it didn't it would be like a trickle into town when in actual fact it would have been like dumping a baby's bathwater out … like a tidal wave. So yeah, that's a different level of perception that people have about their own situational awareness. It was the majority of the township. They refused to leave.'
FM#1	(**on floodplain levees**) 'You can't protect houses by having levees along the river because eventually that just

	compresses the water into a higher flood. Eventually she blows out somewhere, on a floodplain anyway. So we've got to use the floodplain as 'where the water goes' in order to be able to protect towns and individual houses. [Instead of rural levees] the ring levee is specifically to protect houses and so you can protect houses by putting up a sufficiently high barrier and allowing the land to get flooded.'
FM#3	'It's the floodplain levees that are trying to manage floods across whole landscapes – to protect low-value production normally. I mean, why would you do that? … A large proportion of the problems with floods now are because the levees fail and then they just pond the water. If there were no levees there you wouldn't have the problem. It would just drain off. It's this crazy thing where everyone's complaining about the effect of flooding because it's the water sitting around for months on end, but that's only because there are levees. If you got rid of the levees you wouldn't have that problem. But no one's going to do that because they do protect you from more frequent floods … My view, certainly, is the starting point of this is "no more rural levees".'
FM#3	(**practices that increase velocity and erosion**) 'They want to get rid of the water as quickly as possible. In the process of getting rid of it as quickly as possible, you increase the energy and that causes all sort of trouble.'
ER#3	'It's an old engineering myth that you want to get the water away as quickly as you can so you make the channels much more hydraulically efficient. All you do is you basically increase the stream power within the channel and you send that energy somewhere else down the stream.'
ER#3	'The [Queensland] flood inquiry … recommendation that all debris be removed from channels … that term 'debris' is actually interpreted by many local governments and river improvement trusts as natural material. The moment you do that, you decrease the roughness of the channels and they become hydraulically efficient and you compound the problem … [the recommendation] was to remove all natural and man-made debris from channels. Unfortunately, that's been interpreted as removing all vegetation as well' [*Note:* this refers to recommendation 7.4 of the interim Queensland Inquiry report.]
ER#2	'The idea of using crises to spark change. You would hope that our recent events would have been able to do that, but it doesn't seem like they did. In fact, the Queensland response [was] putting bulldozers down channels to make them more hydrologically efficient.'
FM#3	(**flood management that poses risks for environment**) 'People start to question whether you should do this environmental work because of its flood implications. Re-vegetating streams – that has implications for flooding. So the question is whether they'll reverse that politically, if they'll say, "Well, there's too much risk." [Vegetation] slows the flows down. There's more debris around. It just changes the flood peaks, stores more water and deflects more flows, all that sort of stuff. It's getting back to the sort of more natural messy rivers which most people don't like … that's been a big issue, the whole vegetation thing.' 'The other one is rural drainage … most agricultural landscapes are drained which means getting rid of one-year floods and small floods. That's a big issue at the moment because it's just wetter. But we're keen to start tackling that question. If you were to ask me what are some of the major impacts on streams, it's cows and it's draining wetlands and it's rural drainage. There's the same length of drains in Victoria now that there are streams … It's all for drainage, for getting floods away. So for us that's a big environmental issue.'
ER#2	'I don't think that keeping information from people is the way to go, which I think is what's happening a lot of the time now … A lot of that inundation mapping that's being paid for by federal money is just kept and it's very hard to get hold of even for research purposes because they're too worried about how people will interpret it. So I think that's really damaging.'

ER#2	'Unfortunately, [adaptations are] happening sector by sector and therefore inevitably they'll all be maladaptive … how to plan for multiple interests with different approaches, as epitomised by what's going on in the Murray-Darling Basin. They're not going to solve any of those issues until they work out how to include everyone.'
ER#2	'A concern at the moment is the maladaptive potential of plantations for carbon credits – those kinds of economic measures may be backfiring … For farmers who are going to try to move towards making money out of carbon sequestration and implementing large areas of exotic plantations, pine plantations and things in the basin which potentially affects runoff greatly through high evapo-transpiration. So they've got ecological targets for their stem density restoration. Anyway, the work they are doing is just showing how the growth stem densities are really going to affect ground water recharge and runoff into a rock area and wetland areas, with a devastating affect like the climate change scenario. So even they're saying there is a need to reduce the stem depth of the restoration of the upland areas for the benefit of those wetland and stream communities.'
ER#3	'From all the work we did in the national riparian lands program through the '90s, I thought we'd won over the discussion around the importance of vegetation. The problem I see with the floods is that all of that seems to be forgotten and we're back to where we were 30–40 years ago. Going down the same path of creating an even bigger problem.'

5.4.20 Any perceptions regarding institutions, emergency policies or organisational structures that could help Australia to manage flood events that are less predictable (Question 4c)

INS#2	(**a comprehensive, strategic approach to disaster resilience**) 'If you are wanting to build in areas that are a flood risk, then … we have to make sure that their floor levels are a certain height, that the houses are built out of flood compatible materials, which Australia also does very poorly at the moment. Then – do we need to put in infrastructure, like mitigation infrastructure – levees, floodgates, that type of thing … that type of strategic, comprehensive approach to disaster resilience does not exist in Australia. 'Now that we have the National Disaster Resilience Strategy, that does kind of give it a national focus … but our system of federation, we've got three different governments. So you kind of do have to take that local level. But they should all kind of replicate that National Disaster Strategy, at a local level. So it kind of trickles down through each layer of government … local governments, if they're going to be required to take this rather comprehensive approach, then they need to be supported, both financially and politically, which I don't think they have been getting.'
ER#2	(**on flexible organisations**) 'Flexible organisations [are needed to adapt to climate change] … flexible in that they have regular reviews, that they have processes for gathering and interpreting information and sharing information and not set down particular pathways for long periods of time before they can change.'
ER#2	'[We need] management as learning, and so that rather than research being isolated that research is management and management is research … let's use the knowledge that we've got now to actually put some things in different areas for management purposes but also monitor them really well and learn from them. I think that's another kind of flexible adaptation strategy for changing the way our research and management structures work.'
INS#3	(**on coordinating organisations**) 'If you take Emerald Council as an example, a lot of the mitigation that needs to be done in that town has to be done by the state rail, by the water companies. Some of the water companies are private, some are public. Department of Main Roads … the main mitigation that can be done at Emerald is not controlled by the council, but more by other state and federal entities … a lot of it, you need to get four or five government departments to all

	coordinate. I'm sure you've had some experience trying to get one government department to coordinate, so imagine then, five … you need very strong leadership planning from the top to be able to drive change under those situations.'
INS#3	(**policy choices and priorities**) 'Society decides to let somebody live next to a river … three options … You either move the property to land that isn't going to get flooded, you either mitigate the land so it no longer gets flooded, or society just chooses to say, "Well, yep. We know every 20 years we're going to have to give you a new house and that's why we pay taxes" … I do think it is a policy [decision] … once you start saying, "Well, don't worry. We will rebuild your house if it gets damaged" … you definitely don't want there to be an incentive to not take [insurance] out, because you know the government is going to bail you out … it's a really complex issue. But ultimately, hoping and not addressing it is never going to solve it, because it will happen again … Given that, what are we going to do?'
EM#1	'You need to get some strategy and some preparedness and prevention stuff right before we actually start to prioritise stuff in command and control. I would far rather see execution of a really good strategy than a really perfectly aligned and in tune command and control framework.'
LG#2	'I think what really needs to be done in Australia is all political at the moment. I think it's fighting for access to funding. You know where should funds go? What are Australia's biggest issues? I think flooding and resilience to any type of event, not just flooding but bushfires and things like that, they're our priority. I mean there's people's lives at stake, not just on an economic and social and environment basis, but their actual lives.'
FM#3	'I'm certainly interested in sort of incremental environmental and social benefits and reduction of social risk and stuff that normally comes from incremental policy changes rather than big ones.'
FM#3	'My view is that you shouldn't have [rural] levees at all anyway. They're just a dumb idea out on that scale. Trying to manage floodplain flooding at that scale is silly … What you want to do is put in place a policy where you don't need the levees at all.'
ER#1.1	'There are two difficult policy dimensions emerging [for catchment scale flood management]. One is how do you deal with floodplain management where individuals, or small groups, want to direct floods away from themselves, without necessarily having to take responsibility for where the flood will go if it doesn't sit on their land. So we're seeing a little bit of that with levees and flood mitigation works around towns. 'The second policy area is, if you manage the landscape to hold floodwater in the landscape longer, what are the implications for people capturing overland flow and then wanting to use it for other productive uses like irrigation for instance? Now the work done on swales and managing swales so that water will stay in the landscape longer is sort of almost on a continuum with catching water into dams and using it for irrigation. So although the use of overland flow and water management is increasingly well regulated, the idea that you might actually want to hold the water in the landscape in a flood event and bleed it out of the landscape more slowly … the link between the flood mitigation outcome and the capturing of overland flow outcome hasn't been clearly sorted out. In a big event it's probably pretty obvious, but in a medium to small event where it becomes a recharge of storage, as distinct from a slowing of drainage, those dimensions I don't think they're clearly sorted out in a policy sense yet. It could have negative impact on environmental flow of the water moving through the system, but it may also mean that people higher in the catchment could hold water which would be also of value to people lower down in the catchment.'
ER#3	(**legal definition of a river**) 'Rivers are defined by their high bank. But under legislation there is very little setback in

	terms of planning and if you look at the hydrographs of most Australian rivers when they do flow, very little of the actual discharge is actually in the main channel. Most of it's out on the floodplains. You would have to define [what a river is], particularly in a highly variable climate. The river has to be defined by a floodplain, and I think what's happened in these incredibly dry times is that people encroach on that. A lot of structures get built which impede water and all that does is relay the problems and – well, exacerbate the problems elsewhere.' 'There's been some challenges to what a defined watercourse in Queensland [is] … defining the high bank in a lot of these systems is really problematic. 'Wet perimeter', I think, is the current definition, so even now the state government doesn't have a lot of responsibility over what people do in their floodplains and what they do in their riparian land. This sort of issue can't be managed by local scale decisions. In fact, it can be exacerbated by them because you'll get one farmer who will go on their property, recognise they've got a problem and levee up on their side of the floodplain and then simply just push the problem to their neighbour or pass that problem downstream.'
INS#3	(**on managing flood data**) 'Geoscience Australia [is] collating and collecting all the maps … probably one federal [body] running it, rather than having each little state doing their own thing … I think having a consistent data set that's across all states is probably the way. But you need to work with people on the ground, because [they] are the ones that know the truth … but then roll it up to get consistency at a national level.'
UT#1	(**on development planning**) 'Accountabilities are so vague. So what if … you have councils wanting to stop houses on floodplains. You have state government planning departments approving applications to build on floodplains and overriding councils. There is something wrong with the accountability that that happens. Obviously, you know, there's a major flaw in our system. 'Obviously there's an issue there that the planning departments think that risk is acceptable. The councils and emergency services think it's unacceptable. Where does the power sit with it being acceptable?'
FM#2 (QLD)	'We've gone to this performance-based planning system up here and [planners] will talk about acceptable risk: 'acceptable to whom' is always interesting. It's that split incentive. The problem with the management of this risk is the risk is not borne by the developer, it's actually borne by owner. Tennyson would be a classic example of how that risk actually gets transferred. The developer will argue for concessions or – that "we've got it all resolved" and then the failure is actually borne by the person who ends up owning it. So that split incentive is not properly represented. Well it's a market failure in a sense or failure of the system.'
FM#2	'No planning schemes are being rejected for non-compliance with the old state planning policy. In fact, SPP 1/03 in my view is fairly much an advisory instrument.'
LG#1	'I recall seeing a report about how by the year, I think, 2050, land use will have be similar to an area that was there 40 or 50 miles [65–80 km] to the north. So it's all about adapting to that climate as it comes down. But we have to view it with a long-term objective, and the scheme, the governments, and the agencies to have that long-term objective. I think that's what's important. 'The important part is that they do acknowledge that people have to take that long-term view, that's the main issue … that there is a change there and some of the history that we're looking at through previous events is there and it needs to be carried through into a longer term view by the agencies concerned.'

FM#2	'Should [we] have a floodplain management authority? … I think to actually have a standing institutional structure is not indicated by the frequency of events.'
FM#3	'Between floods, you've got to keep the pressure on. You need some sort of independent player … you need a [planning] regulator to make sure that everybody's doing their job in this sort of space between events. There's so much impetus to *not* do it and so I really quite like the model where everyone has their role but somebody – some independent entity – sits out and says, "Well, in this plan you said that you were going to produce a flood overlay and you haven't done it." It's just as basic as that … governments quite like independent entities like this … 'They're talking about a big emergency services department in Victoria that covers all emergencies. They could be the entity who did it because they have to live with the consequences, which is the danger to communities. So they'd be watching, always saying, "Hang on, you've just allowed six houses to be built in an area that's going to be flooded. That's going to put emergency workers and the state at risk. What are you doing?" Or, "You said you'd have a flood overlay put in and you haven't done it."'
UT#1	(**on achieving a catchment systems approach**) 'One of our problems we've created is these highly specialised disciplines, but we've poo-pooed people that have broad-scale knowledge. Really, for good systems thinking you actually want people with broad-scale knowledge, so I think that's a whole – it's actually a very complex issue for another day. It's about having multidisciplinary teams.'
ER#1.2	'One of the key messages is that no matter what individual interventions you make, you will have very limited success unless you take a catchment-wide approach. Because of the complex way the landscape functions, you can't actually really isolate the impact of one small intervention without using that broader catchment approach. 'The way we're trying to work that in is through some of our catchment planning approaches that are happening in Queensland, such as the South-East Queensland River Recovery Initiatives, which are being led primarily by the local governments around the South-East Queensland region. 'To take a whole catchment approach to planning and for river recovery in terms of natural resource management interventions as well as their actual urban planning practices, I think stormwater quality and total water cycle management type approaches all [need to be] integrated into these catchment-wide plans. Which involves a degree of collaboration between the local governments, because obviously a river catchment doesn't stop at local government boundary.'
ER#2	'Part of my ignorance about these reviews demonstrates substantial segregation in the communities that should be involved in this kind of work. So you've got lots of ecological work going on. For instance, in South-East Queensland …[there are] other people at Griffith who've got awards from the Healthy Waterways committee for their work looking at the effects of the floods on seagrass and mangrove communities. They demonstrated how resilient they were, how they've recovered quite well after the floods. But these kinds of things go on in isolation from the engineering.'
ER#2	I think organisations like the Basin Authority are headed in the right direction to have these kinds of broad-ranging powers over a geographic region.
ER#3	'This requires a level of spatial planning and prioritisation and in fact optimisation beyond the ability of the individual landowners – beyond the ability of most councils … When you look at it who's got the ability … from a legislative point of view, in Queensland – who would have the authority to take responsibility for actions on

	waterways? That was the former Department of Environment and Resource Management … they have legislative responsibility on watercourses … no one should be doing any works in channels without licence and authority through them.'
ER#3	'Local governments have got responsibility for floodplain development and planning, and so it's really about training and informing them in all these things about river behaviour. Then there's this element of catchment prioritisation that … I think is well beyond the scope of any local community group.'
ER#3	My experience is [Catchment Management Authorities] have got very skilled people working for them. If have got good governance, they are able to plan activity within them at a reasonably logical catchment scale. Still, sometimes they can be captured by local opinions. So there's still a need, I think, to have some sort of expert advisory or review process in play.
EM#2	(**on the Commonwealth's role in disaster response**) 'The Commonwealth actually doesn't have a role to play in disaster management. It's not a Commonwealth constitutional responsibility. It's something that the Commonwealth bought themselves into through the provision of disaster assistance … I've heard some views expressed that the Commonwealth should be responsible for disaster management coordination and direction. That really – that's not a Commonwealth responsibility at all. Do we have disasters that large that we need to manage [across borders]? Well, at the moment there's a lot of cross-border arrangements in place and we actually have bilateral agreements between jurisdictions which seems to work really well … there hasn't been evidence to suggest that should be changed and that we need a central government coordinating mechanism directing and controlling … If we're requesting assistance of the Defence Force – and we do – then quite clearly that's a Commonwealth responsibility. It's costing us so much money … there has to be a different way and we have to do things better. But that's not a response issue.'
EM#3	'In the state of Victoria, we don't have any mandatory evacuation powers … we can give an evacuation notice which really is the recommendation that you should go and you should go now but there's no enforcement.'
EM#1	'The legislative base for flood planning. So at the moment, it's fairly optional for councils and other responsible bodies to elect to do flood planning management plan and studies. I'd like to see that being more of a legislated thing that councils, if they identify that they do have a flood risk, need to develop a relevant flood plan risk management plan and I think it also should be legislated that emergency services need to have relevant plans themselves, that plans need to be regularly exercised.'
UT#1	(**on the advantages of the mutual aid arrangements for the Australian water sector**) 'We see it not just being about exchanging resources, but actually exchanging knowledge. Because, again, with an ageing workforce the knowledge is leaving, so it's about how we effectively share the knowledge across the country. '[During] the Brisbane floods we used to have daily phone link-ups and anyone who had any sort of experience or knowledge from previous events would pass it on to people experiencing that event. A good example too was in the Victorian earthquake recently – we had Hunter Water, who'd been hit by the 1988 earthquake. They gave extensive briefings to the water companies down there to what to look out for over the next couple of weeks.'
UT#1	(**on reforming the emergency services sector**) The emergency management sector is an isolationist sector. It is poor at partnering with non-emergency services organisations, it is poor at information exchange with non-

	emergency services organisations. It doesn't see the importance of the essential services sector. The solution to that is through partnering – that comes from joint training and joint exercising … That's a state and a national issue because the Australian government runs the Australian Leadership Management Institute, and it needs to make a decision about how important it sees that mixed-class environment [as being] versus just targeting emergency services people.
UT#1	'How you then change around to… "you're responsible for your own safety, you're responsible for being a partner in your own resilience", which is the national agenda now … federal governments are the 'come in and save you' people. I think that's going to be a hard mindset to change … We don't seem to be pushing [the "you're on your own for 72 hours" approach] quite as hard and we certainly don't have uniformity across the states...We have all little independent emergency services pushing their own individually packaged messaging. There's no consistency, there's no reinforcement and it's just inefficient.'
FM#1	'[Managing flood events or recovery] often relates to the personalities and the capability of the people there, rather than the institutional arrangements … in the immediate post-flooding things, it's far more regimental and each time we have a flood, we learn how to do those things better. Then the people change and the knowledge and experience tends to diminish with floods over time and then you get another one. Whereas our bushfire responses are really good because we virtually get one every year … floods we get one every 10 years or something – or 20. So the people that managed the flood response this year are different to the ones that manage it next time. So all of the learnings that are in people's heads are gone, so you need to have processes that acknowledge that the experience factor is likely to be very limited in a flood.'
FM#1	(**on regular joint training exercises**) 'Agencies' appetite for those training exercises tends to wain over time as well. So even though in theory that's great, there needs to be something that locks it in, because if you don't, the next manager that comes along might think that something else is more important and it gets lost.'
FM#1	(**on the government's role in reconstruction**) 'People have chosen to live there. It's a floodplain. To some extent, they've accepted the risk. When things go wrong, what's the role of government? It's to provide – meet the immediate needs in the emergency context but longer term, when a milk bar owner goes broke because the supermarket moves in next door, the government doesn't do anything. There's a whole lot of things that happen in life where the government doesn't intervene, where you sort of say, "Well that's life, that's the market operating". Well in this case, people have chosen to live in a floodplain and that's a flood operating. What is the role of government?'
INS#2	(**approach to reconstruction**) 'There doesn't seem to be much in the way of a central depository or a clear collection of information about best practice in reconstruction. I think maybe the bushfires have helped that – the bushfire element. I think establishing the Queensland Reconstruction Authority and the Reconstruction Inspectorate, at the federal level, will probably help going forward. But we've been dealing with floods for many years in Australia, and there hasn't been that kind of systemic approach to reconstruction.'
INS#2	'You would hope that one of the outcomes of these [flood] reviews, and having the Queensland Reconstruction Authority, [is] that there is something to put in place, to ensure that, in reconstruction, principles are built in extremely strongly for spending money in a way that builds the resilience of the structure and houses, on an ongoing basis. [In response to the above comment, the interviewer queried whether the QRA was a good model for building resilience in the reconstruction phase. Discussions around this suggested a review into the QRA's effectiveness would be useful.]

LG#3.1	(**on the Queensland Reconstruction Authority as a model for recovery: negatives**) 'They came into an existing system that had been stretched but created a whole lot of new systems and processes. That cost us a lot in terms of momentum and created a lot of angst through those that were already in the system.' 'They just basically took over, paid no mind to the resources or the processes, the systems that we already had in place. They started producing doctrines that already existed. So that created a whole lot of issues for several months.'
LG#3.2	'My deep reservation about this as a solution, though, is that anything that's fundamentally based on the idea that we need a major-general to fix it is so broken that it's not worth fixing.'
LG#3.1	(**on the Queensland Reconstruction Authority as a model for recovery: positives)** 'They've centralised things like NDRRA, which every year since the system started has been a big job here in Queensland. But it was managed by several different agencies, depending on whether it was an infrastructure project, a roads project or any of the other elements of NDRRA – we're across three different departments. All of those people, all of those specialists, are currently seconded to the QRA and that has worked a lot more efficiently and effectively. So hopefully that function will stay centralised and belong to some agency post February next year.'
LG#3.1	'They've also been able to draw on resources that would not have been available to other agencies around the state, even though it's their core business to do things like flood mapping. To produce documents like "here are handy hints on how to rebuild in storm tide areas, in cyclone areas". A lot of the stuff that they've produced could have been done by the existing agencies but they've never had the resources to do it. Suddenly they've been given the resources.'
LG#3.2	'I think the great benefit that it brought was sustained effort for a much longer period of time than we might have expected out of the normal system. In my view the normal system would have long ago been under pressure to go back to its normal business and for people to be sent back to their substantive positions rather than continue with a State Recovery Committee or continue under the suggested model.'
LG#3.1 LG#3.2	(**QRA and its role in the Grantham relocation**) '[The Grantham relocation] is a classic betterment case that wouldn't have had a hope … [to] get the resources to make that happen couldn't have happened without the profile and the political will that the QRA has enjoyed. Over several years we've had similar arguments about relocating parts of communities or funding the raising of houses that are right on rivers or the buyback schemes for some of the most at risk properties and absolutely no appetite, no appetite whatsoever for that.'
LG#2	(**on a proactive approach to betterment**) 'A program should be implemented sooner rather than later to actually identify all potential issues. Then slowly but surely progress towards improving those, so an improvement program, things like that. So there is funding and that available after an event, yes, but I think on a larger scale Australia needs to implement more programs into an entire betterment scheme. Rather than just a flood recovery betterment scheme … Local governments are probably the best situated to understand what occurs during an event, things like that, and to provide proper comment … [Local governments] survey, identify, do hydraulic studies, things like that. They need to be done, they need to be put into a program and a potential progression of works and a priority listing. That listing should be submitted to a national scheme.'
FM#2	'There is definitely a failure in the system what that suggests is that there's an information gap that can't be filled in the timeframe that's required to respond to the broken roads … You need to preload the information about "in what contexts?" and "what's the cost?" – people need to know if I make this decision to allow for betterment

	it's going to reduce our long-run costs by whatever. I don't there's sufficient research done to justify betterment. Certainly in the minds of those who are making the decisions.'
ER#2 (QLD)	'The recovery effort was incredible. What it points to is the capacity to have flexible integrated organisations. So why can't we do that with an eye to the future instead of just cleaning up?'
EM#1	(**on the review process**) One of the downsides of the review process is that the government reviewers are able to engage with the communities to establish basically what the community views are, but makes it difficult for agencies to then potentially go in and engage with communities at the same time. So that's probably a small one but still a strong issue.
FM#3	'Straight after the event, as actually a public service, we recommended that they do this inquiry knowing that all of the problems needed to be resolved. Having a parliamentary process gives much more credence to that process.'
FM#3	'The first reaction of the public is to blame somebody, and I think it's important that you have some sort of process to – and quickly, to decide whether that's justified or not … part of the problem is just people don't understand floods.'

5.4.21 Resourcing mechanisms suitable for less predictable flood events (for both prevention/preparedness and response/recovery phases) (Question 4d)

ER#2	**(on funding cycles)** 'That's an obvious thing … that our funding structures are around annual financial years or maybe three-year funding cycles and then you might only get these events once every 10 years or whatever … [we need] backups available for events and strategies so that when events do happen there can be a response from managers and researchers.'
INS#1	(**On obtaining funding for mitigation**) 'At the moment, federally, they have a bit less than $30 million a year to spend on [mitigation]; you can't really even build one levee for that. 'It's a very, very complicated process of local government needing to build a business case and raise one-third of the money, then convince state government to chip in a third of the money so there's a whole bunch of justification and cost benefit analysis that would have to be done for the state government, and then the state government needs to justify it to the federal government, yet another business case and series of plans et cetera to get one third of the funding from the federal government. So that's an awful lot of work to do and the costs of even starting down that project with no guarantee of getting all the funding are quite considerable. So often multiple millions of dollars to just get to the point where you might get approval and full funding to do the project, which strongly dissuades some smaller councils who might have high mitigation needs from being able to embark on the process at all. So we've been calling for a bit of a top down review of all that … it's the funding process and approval process that needs to be reviewed because right now it is clearly not able to produce the mitigation results.' The results we need to see are fewer homes getting flooded on a less regular basis.
FM#1	'There's going to have to be a funding model put in place in order to be able to ensure … the ongoing maintenance [of floodways and levees] is looked after. So I'm assuming that the type of model you'd be looking at is, government would invest in upgrading the infrastructure in the shorter term through some annual five-year plan, for example. The beneficiaries, the community, would need to then – through rates or a special levy or

	whatever – contribute to the ongoing maintenance and there would need to be an agency that was charged with the responsibility of looking after that, like a catchment authority or whatever.'
ER#3	(**on funding priorities**) 'We worked it out that the total cost of halving the sediment delivery to Moreton Bay was the same cost as upgrading 20 km of freeway between Brisbane and Ipswich. It really just requires a shift in priority. We've got no problems spending half a billion dollars on upgrading a freeway or building 600 m of a bus lane but you try and invest in riparian infrastructure or floodplain infrastructure … there's no appetite for it.'
ER#2	(**on integrated funding**) 'There's just a real need to integrate across disciplines and sectors and get some processes happening for prioritising those resources and also piggybacking off other developments.'
INS#1	(**on funding for flood risk mapping and assessment**) 'You have to spend quite a lot of money in getting your own initial flood study done to prove the case for a more in depth one to be done with federal funding … the process is too complicated for individual councils to even start to contemplate applying for funding in some cases … some councils are too small and not rich enough to afford to do good quality flood mapping … where they've got the risk they should have the first federal funding and state funding to get it done. '[Queensland Flood Reconstruction Authority Flood Maps are] a great mechanism for the local council or the local authority to say okay, according to those high level large resolution maps we have a business justification to go and spend money or apply for a grant to do detailed mapping in that area.'
ER#1.3	'At the moment the local governments are trying to put together risk assessment plans for their individual areas and they're trying to follow national guidelines. But obviously a lot of them, the smaller councils especially, don't have the resources to do that. So the Local Government Association of Queensland is trying to help them as much as they can, so that they can incorporate all these risk assessments across the board.'
FM#3	(**on appropriate floodplain development**) 'Local governments benefit massively from development of floodplains … if everyone gets flooded then the state government or the federal government come and bail them out. So the cost to communities is usually modest. So I reckon you have to increase the price signal to local government. If you make a planning decision that screws up then you need to wear the price of that.'
ER#2	'[There's] all kinds of new construction – Southern Cross University has got a new building near the Gold Coast Airport that just floods after rainfall. It's unbelievable. Byron Bay built a new cultural centre and sports field on a floodplain using … the economic stimulus package. So almost $20 million on these fields which now, since they've been finished last year, none of the sports clubs will sign up to them because they're just constantly waterlogged. So there's a management change that will be required. That kind of federal money should definitely not be going into projects like that.'
ER#3 (QLD)	(**on funding catchment-scale approaches**) 'Our [Catchment Management Authorities] are set up and are trying to maintain a lot of their activity through lamington drives and scrounging for funding.'
FM#1	(**on Payment for Ecological Services schemes for catchment-scale flood mitigation**) 'If someone would pay a comparable price for ecological service as they would for agricultural purposes, then obviously there would be no problems. But if it detracts from the deed of the land in some way, then we would struggle with that as concept … so

	allowing land to flood is a social service, in the sense that if this land takes the flood then somewhere else gets the benefit from having the pressure relieved. If it's the type of farming activity that can take a hit every now and again, then that's probably not a disincentive. So if there's the money to compensate you for taking the occasional hit and some money to pay for ecological services, then I can see that potentially it can become a business. It's sort of a low-risk farming business plus a flood mitigation business. So if there are a few beneficiaries – it's just working out what the funding model looks like. Who the beneficiaries are and who pays.'
FM#2	'Who would pay them? The people of Gatton who live on the river who don't get quite as flooded? Or the people of Brisbane who live on the river who don't get quite as flooded? The insurance company who's seeing the damage bill reduced by half a billion dollars because the water's being stored on people's farms up in Laidley?'
FM#2	'It's such an interesting regulatory problem in the sense that you're jumping the fence to make these works happen on private land. Then managing the flow of water for public benefit. So you're actually going to say, this storage can store water when you've got plenty on your land anyway but after that if it's dry you can't store water in it.'
FM#3	'What they've done [Trust for Nature] is they've bought up big slabs of lowland country in northern Victoria where they are suggesting that they will provide services to downstream landholders where they'll store the water on their property in wetlands and in other areas to protect downstream land users. Which is a good idea. My problem is, I don't know what the scale is. Are their properties really big enough to make a difference? They've got to have a fair bit of water … they've just come to government for support and for co-investment … But I think the hydraulics have never really been well enough established. What's the actual effect?'
LG#2	'It would be an encumbrance of their land … For Australia to try and implement some type of scheme like that, I think there'd be more involved in regards to the areas that would be required to be encumbering primary production land. I think the restrictions and issues that primary producers currently have, you'd basically be sending them out of business … Not only [compensating farmers], I mean we're restricting what we eat. Are we going to import all our food from then on? Yeah, I think there's a lot of issues involved in any type of decision-making for [land use].'
LG#1	'I'm stating the obvious but if someone chooses not to maintain a bank in their particular area, the impact on them maintaining it can be felt 2 miles [3 km] away as the water flows through and continues on its merry path into adjoining land holdings and around. So there's a lot of pressure. So when you have … Trust for Nature type people who come in and buy land in the area – and this isn't a shot at them – but they don't see. Essentially their view is that the land should be returned to being a floodplain and their preference would be for the bank not to be there. The impact of that bank not being maintained does affect the land owners around them so there's a lot of dispute.'
ER#3	'People *are* paying for it I guess, aren't they? They're currently paying for it in the cost of the water they drink. Farmers are paying for it – the cost of lost land [from erosion]. So in a way we *are* paying for it. Yeah, I think it's – if you look at the return on investment for doing this, it's quite easy to demonstrate that people will get a value for money. A lot of the time though, of course, the people who are going to benefit are not in the areas where you actually have to do the work.'
ER#3	'If you're going to reduce the actual damage to property downstream, there are benefits that are being felt there in terms of insurance payouts and everything else. So I guess there's an avoidance cost that people living downstream should be prepared to pay. There's a service cost in terms of clean water that the water quality and water management side of things, which is a big part of the upper catchment. There's nothing unreasonable about factoring that into the cost of bulk water delivery as well.' [see Sedimentation issues for latter comment]

FM#1	'We've had interest from Trust for Nature … the government generally pays for ecological services but in our particular case, the government thinks that they've paid enough [for the Lower Loddon buyback] … if you put special governance on the land which limits the type of farming practices you can do, you limit the attractiveness of that land in the future market. The state Treasury fully expects us to put this on the market and get a commercial outcome and get some of their dough back.'
EM#1	(**on funding community education**) 'There's potential in the future for developers to contribute more to things like community education. The government could say, "Righto developer, you put a development on a floodplain, you are now responsible for ensuring that there's adequate money for community education of those residents into the future." So set up a fund which then will supply agencies with money to do education for those areas. So there's those sort of models which I would see working.'
EM#1	'We have been constrained more broadly about raising community preparedness afterwards, just because we simply don't have the resources available to do that. We do have some more resource available now … but directly after [the 2010–11] floods, we were very constrained in the availability of our resources to re-engage with some of these communities.'
LG#3.2	'We adopt the national approach of a comprehensive approach to disaster management and so it's a cycle of prevention, preparedness, response and recovery, but the funding is not there to support each stage of that cycle. So when the response phase is larger, more demanding than we're set up to manage, that's when the system stretches and sometimes breaks.'
LG#2	(**on funding resilience**) Keep the funding going … with regard to local government where there's a requirement for asset management plans and what costs associated with each asset does it take to maintain those assets. First of all we need to be able to afford to maintain what we have and I think that all, if not most, local governments would actually struggle to maintain those assets the way they probably should be. To go out and look for any more type of resilience you'd need more funding, which would be more obviously federal and state kind of funds, to be provided.
UT#1	(**on resourcing disaster response**) 'New South Wales is actually just launched a review on how it funds its emergency services … I'm guessing they're going to move to the South Australian model, where there's a levy put on every rate notice, every car registration, every truck registration, every boat registration, etc. So that cost is spread more evenly across the community rather than only the few people who pay insurance.'
EM#2	'If you had a different disaster management system in place, would people have lost their lives? What sort of resourcing would you have had to put in place in a place like Grantham which you probably wouldn't have expected that it would occur anyway? … Where do you place your resourcing? 'How we resource volunteers, we can probably always do a little bit more in relation to that. Our cost cutting in Queensland will probably see us resourcing less rather than more.'
EM#1 (VIC)	'We're reliant on the government for our funding. We do have some partnerships, which provide us with some additional funding and some grants for flood safe programs and what not. Interestingly enough, our community education programs are largely not funded by government. They're funded through partnerships. So we've got a partnership with Melbourne Water. We've done some work with Bendigo Bank in the past. Also, through the Natural Disaster Resilience Grant Scheme. But during events we're reliant basically on the natural disaster relief and recovery arrangements for additional funding.'

LG#1 (VIC)	(**on funding disaster recovery**) 'I can't fault the federal or state government in that regard. They have been fantastic to us. It went really well. They listened. They understood that there was a lot of work out there, it was very hard to measure the quantities. We went with a schedule of rates type contract rather than a lump sum because you just couldn't quantify the extent of work out there, you could get a general grasp on it and look they have been be fantastic. I'm amazed at some other municipalities that they said that they weren't able to deliver the program … within the two-year timeframe … Some people will tell you that the timeframe hasn't been long enough, but I'd argue that if your community can withstand having damaged assets for that length of time you're not really trying.'
INS#1	'We don't want to see the state bailing people out on a consistent basis; we just can't afford that as a country. So last year I think, if you don't take into account the infrastructure costs – which were about $5.6 billion in taxes raised through that extra Medicare levy that we all paid – there was another $800 million in handouts given to Queenslanders by the government for the impact they suffered. Yet nationally there was only $30 million of mitigation undertaken. So it's completely wrong; it's completely out of whack … [the government] can certainly find the money to pay out people post-events; we think they should be finding the similar sort of quantum pre-event to prevent the problem having ever occurred.'
INS#1	'[There is] a very strong shift towards "you pay your own way, you pay your own risks". But of course that's predicated around people knowing what their risks are … quite often communities don't understand what their risks are so they're not in a position to make appropriate personal decisions about how to protect themselves. So I think in those cases the state needs to bear some responsibility where they have failed to inform people properly or where it can be proven that they have in fact been negligent in not doing that.'
LG#2	'There's people that have built in floodplains that are known floodplains, and are well aware that their property could be inundated. The finances spent on recovering that area is also coming from the people who don't live in that area … [an equity issue] and in local government obviously we have to stay diplomatic. But there are those thoughts out in the community.'
INS#2	[Discussing federal disaster relief funding of $800 million to individuals in $1000 payments] 'The activation criteria were pretty loose. The eligibility criteria were pretty loose … I just think it was a waste of money, frankly. There were other state grants and state assistance to help people in terms of providing food, shelter, immediate assistance. So giving them a grant and the cash in hand is pretty much useless.' 'Would it be better – rather than providing that type of payment, that doesn't actually support people who've been affected – would it be better to be putting that type of funding into subsidising retrofitting houses? Getting people some extra cash if they want to raise their house, if they want to refit their walls? Post the disaster would be, obviously, the easiest way to do it because you'd be able to identify the people who were most at risk, and it would be a part of the rebuilding process. Could you also have a scheme that's always run where people who are in that area that's been considered flood prone are able to apply for funding, to subsidise building materials or stuff like that?'
LG#3.1	'It's the social conscience that governments have to have, really – I mean, that's one of the reasons why we vote for these people, that they're there to help afterwards and they're not brave enough to – and sometimes they don't have time enough to do even just a quick check to see whether (a) the person really needs stuff replaces, (b) whether they can afford to replace it themselves, whether they've got any insurance. There's been any number of relief funds that have come unstuck for lack of those checks and balances.'

LG#3.1	'You have a look at the agencies that fell over themselves to help the communities … during 2010–11, and the political popularity that followed. But that popularity disappeared almost as quickly as it came. So it's really a short-term gain politically. People might appreciate it that day, but the following week they've forgotten about it already. So do you put up with the short-term pain for the longer term investment? But again, it's the effort you invest before the event.'
INS#3	'All that money that you and I have been paying as a flood levy out of our pay packet over the last year or two, I do think they need to go and start mitigating in places like – in known towns where things flood. Like Emerald, like Roma, like Chinchilla, like Brisbane. Because it will flood again.'
EM#2 (QLD)	'NDRRA at the current formulas work very well for Queensland because we have lots of natural disasters … it's on the sliding formula starting off at 25% Commonwealth contribution, 75% state. But once it gets [to a] dollar threshold, it swings around … for the floods, it was 75% Commonwealth and 25% state contribution. Of course, we're always above that threshold because of the number of disasters we have … 'Victoria … normally their disasters are at a lower level. But we're always running at that contribution level so we benefit greatly from NDRRA in terms of assisting local governments put their infrastructure back in place.'
EM#2	'The National Strategy is signed off by COAG but that doesn't mean governments have necessarily adopted the betterment provision. In Queensland, we look at betterment on a case-by-case basis and there is some betterment now occurring … should we be using National Disaster NDRRA monies to essentially rebuild to a better standard? … They're designed to be an assistance scheme … If NDRRA didn't do it, where would that funding come from?'
LG#2 (NSW)	'We struggle to have resources for reconstruction and recovery. We struggle to get funds approved in time. I mean I'm still waiting since [October] 2010 for the approved funding through the Public Works Review. I still haven't been approved for that. So work's been undertaken in between but those funds had to be covered upfront … We haven't quite submitted our March 2012 one yet because it's quite a bit more extensive. But we're not far off doing that. But my thoughts and worries are that, you know, do I have to sit there and wait until I can get some funding to actually go out and maintain a lot of this large-cost asset rehabilitation? So two years to wait, we could incur another event and we probably won't have the same level of protection. But that won't stop us from doing it. It just means that other projects and initiatives that local governments would have had – the program for those years – are delayed or deferred for several years.'
LG#3.1	(**on funding betterment**) 'If we raise the depth [of a bridge] by 1 m and [damages] only happen every 10 years, then all things being equal, that's a good investment. But there isn't the will, and to be fair, the money really, at state or federal level to invest in that project for gains down the track, two or three political cycles away, for a weather event that may never occur or may not occur for 20 years or 50 years when the bridge may well need to be replaced anyway.'
LG#3.1	'NDRRA took the big leap only a few years ago to fund the replacement of a piece of infrastructure and upgrade it to current engineering standards. Bizarrely, the requirement was to restore it to its original standard, not the current standard. So betterment is the next step in that logical sequence.'
LG#3.1 LG#3.2	'The clock starts ticking as soon as the event occurs in terms of community expectation for restoration, in terms of your obligation to restore that function, or that service, as soon as possible. Once you start the emergency repairs. you're then heading down the path of restoring to the standard it was back to previously so you've lost really the opportunity.

	'The Catch-22 element is the length of the process [to approve betterment] … [a] good example was one of our Indigenous communities that had the only road into their community … the ford there was completely washed away. They actually had the choice between, do we actually leave our community disconnected from the outside world for a period of time while we wait for these decisions to be made, or do we start with a restoration piece of work. Somehow they managed to hold firm long enough to get an upgraded causeway approved.'
LG#3.2	'[A] problem with betterment is that it's really difficult to do it before events. So there's some opportunities under the Natural Disaster Relief and Recovery Arrangements if you're smart enough and quick enough and have the skills to build an argument around your application to get some of these things up. But true mitigation would actually suggest that 'this is a high-risk piece of infrastructure so let's replace it or upgrade it before it gets hit'. The difficulty with that is that … it then has to go into a different line in the budget and become part of the actual budget proper as opposed to where it sits at the moment. There's been a huge amount of money that's been sitting in a contingency fund for post-event reconstruction and recovery work, as opposed to preventing reconstruction and recovery, which is an investment that has to be part of the budget papers.'
LG#3.2	'It's a Catch-22 situation in that once they identify the problem beforehand, they then have to put it on to – their duty of care and their financial responsibilities and all of that require them to put it somewhere on their schedule of works. Once it's on their schedule of works it may not technically be eligible for betterment because it's part of a normal works program that's now being diverted into a betterment program. Whereas if you don't do any of that thinking beforehand and the event damages, then you have to quickly throw together the project and the argument for [betterment].'
LG#3.1	'Certainly our state government, and I know the federal government, are looking for ways to try and minimise the financial impact of disasters … But trying to get some money to spend on mitigation, this whole idea of betterment before the event … "we're going to spend $1 billion on infrastructure but we're taking it out of the health and education budget" is not really a good news story for the federal government.'
LG#1	'It's about having an agreed process. So what I would like to see … is maybe having a recovery representative from the funding body and in our case – our gentleman's from VicRoads but I think he's doing a number of municipalities. I think – with the extent of work, he should only be with a badly affected council like ours which had $24 million worth of damages. I think it probably wouldn't hurt to spend potentially $100 000 in salaries for one particular person to oversee and give approval to an agreed improvement to a specific structure. 'In our case it would be post- but I think it's called "pre-improvement". I think it's going back now to get our communities better prepared for the future flood event. It's about having that pre-approval. Okay, if this blows out next time, we are going to repair it in this fashion. 'When the flood studies were done … it was identified in that flood study that when that road was to be rebuilt it was to be considered to be raised to form the bottom section of the levee … in the future capital works, it's acknowledged [for] when this structure is up for renewal and I think it's just putting that rider in there, that all damage, that it is actually improved to this standard.'
LG#1	'You're going to have … this argument, "Okay, who's going to pay for that upgrade?" because councils are always claiming to be cash strapped and that's fair enough, everyone's struggling for resource. But I think in this process, if you are looking to do betterment, then maybe that particular project should be able to go on a longer program rather than being locked into the 24-month timeframe [for completion]. All of this other

	work … we can do that within the 24-month period but this one's subject to betterment so therefore it gets a longer lead time.'
INS#1	(**on resourcing mechanisms to help people to relocate or rebuild to better standards**) 'They were very ad hoc and very localised.'
FM#1	'We've got a program … called a modernisation of irrigation infrastructure. But it's actually contracting the size of the irrigation district. That's consistent with the Commonwealth government's – the Murray Darling Basin Plan's – buying a truckload of water. So there was money to purchase the water, there was money to contract the infrastructure and then there was the market value of the land. So we were able to offer over-the-market-value with these other components, which made it pretty attractive for people to get out and move on with their life and go somewhere else … [we got] advice about where the boundaries were between the moderate- and the high-risk zones. So we focused on the highest risk areas, bearing in mind that we had a budget of about $12 million to spend on buying these properties [in the Lower Loddon] and probably another $8 million from purchasing the water for another program and the modernisation stuff. So we probably had $20 million to play with. So that helped us put a boundary on the area that was at greatest risk.'
LG#3.2	(**on enabling purchase of the most hazardous sites via means such as preferential purchase orders**) The government, whether it's local or state, has to have a bucket of money to access without any processes. So you can't say, "This person wants to sell their house today so we've got to go through an application or an approvals process." It almost has to be a pre-approved bucket of money that sits there until it's required.
UT#1	(**on discouraging rebuilds in most flood prone areas**) 'In the end, that's got to come down to either a financial or a regulatory driver. So you either regulate and say, after a flood event, there'll be an analysis done that takes out the most highly previously hit houses and buys them up. Or has an order put on them where they can't resell them but the government buys them out when they die. 'If you were to remove flood houses from the flood plain, you've just really got to think about who gains them and who should pay. Certainly if you look at the models we have in Australia today, it's been a tripartite between council, state and federal governments putting in. That's probably is the answer going forward for that.'

5.4.22 barriers and opportunities for communities wishing to reduce their risk and vulnerability to less predictable flood events (Question 4e)

INS#1	**(on insurance and betterment)** 'Insurance is only responsible under the contract for reinstating the property is as, but just about every insurer will allow the flexibility, if the person wants to improve the property or change the property, to use the insurance money to help with that. But they might be required to throw in some money themselves. So there's no concept of betterment in the average property. So an insurer, if left to its own devices and the client's wishes, it will simply be reinstating the property as it was before the events, which might mean that it's exposed to the same level of risk.'
INS#1	'In Brisbane, for example, our estimates are that probably 50 per cent of [those homes that flooded] can be mitigated against so that repeat flooding would not occur. I don't think you could mitigate away all problems … from an insurance industry perspective, if you get rid of 50 per cent of the problems, those 50 per cent of people would be able to insure their houses into the future. So that's probably not a bad place to start.'
INS#1	**(on including provision of betterment in insurance policies)** 'That's a private market driver, and we are starting to see some policies now where that is included. So there might be a plus 10 per cent, plus 15 or plus 25 per cent factor built into

	your sum insured to allow for some form of betterment or risk reduction. But there's normally a co-contribution required for that from the client, so I guess that's a trend that we're starting to see in there. Will that become terribly mainstream? I don't know, but if the community starts to demand that by looking for policies with that kind of capacity the market will absolutely respond to that and start including that in more policies.'
INS#1	**(on insurance and relocation)** 'Insurers who had insured property down on the flats were able to say "Yes, absolutely we will rebuild your home up on the hill, you just tell us when and where', but again they've only got that physical limit up to whatever the sum insured was to get the work done. So the owner of the property may get a government grant to assist with the shortfall or in some cases there's been no shortfall at all. So insurers can rebuild for you wherever you want in whatever state you want and whatever condition you want but there is that hard ceiling of the sum insured that you've selected. And that doesn't necessarily mean if you can insure for $200 000 that you're automatically going to get $200 000. They'll look at what would it cost to rebuild or repair your existing property and that might only be $100 000. So that's what you'll qualify for if you want to bulldoze the lot and go and build somewhere, else, only the $100 000.'
UT#1	(**on attitudinal barriers**) 'If you look at Western humankind, we obviously like to dominate and think we can rule the world. So instead of trying to live with the flood, we've tried to dominate the flood. So we actually decide we can stop a flood, we can manage a flood, which I think is complete bunkum because nature will just make a bigger flood and we'll go, "Oh dear, measures didn't actually work" … I think there's a whole psychological problem there about how we deal with nature.'
UT#1	'It could be another 40 years [before it floods again], in which case probably not a bad gamble, because we're gamblers … the whole concept of risk.'
UT#1	'The difference is [between countries like the Netherlands and Australia] they've been around for more than 200 years. If you've been around for 2000 years you have a long-term view of what society is … when the Germans come out to work with us, they go, "Why are you building that? That's like good for 40 years. We build things that are good for 400 years." So we don't think we'll be around in 40 years because that's the nature of Aussies, we're Johnny Come Latelies who don't think like that.'
LG#3.2	'There were people who attempted to claim that this was a catastrophic event and … that there was in fact nothing we could do. So there's nothing to be learnt from it. That kind of pervaded a lot of the post event thinking. That it didn't matter what we did, it was so grand and so big that we couldn't possibly be expected to do any better, which meant that 12 months later when we rolled around to the next event, there were still a few who in my personal view were still a bit punch-drunk from the year before.'
UT#1	(**on demographic changes**) '[If you] add an extra 20 million people to Australia in a very short timeframe, well government has got no option. If you look at Sydney and Melbourne … part of that population will be on flood plains … the government's been forced to because voters want that … In Melbourne now, they're going to pull down 40% of the housing in Melbourne between now and 2050 and rebuild it into high-density housing. Well that's on flood plains, so there is a nexus of a problem there … Sydney's about to build a lot more on its flood plains – there's some big announcements coming.'
EM#2	(**on socio-economic issues**) 'I don't know whether people actually make those sort of choices [about where to live] … most flood-prone areas in cities and regional towns tend to be the poorest area in town and people live there because they can't afford to live anywhere else. There's semi-industrial areas, the borderline type areas. People don't choose to live there … Floods are a discriminatory disaster event. A cyclone comes through and takes out everyone in its path.

	A flood comes through and it tends to take out the poorer dwellings and the people that aren't able to assist themselves to recover, the people who don't have insurance or don't have adequate insurance … I don't really think that people will make a conscious choice, "I'll live here in a flood prone area and insurance will cover my costs." I don't think those people are making that sort of rational choice. 'That 100 year event … you'll get a whole range of profiles. But those places that flood regularly … in Brisbane you would look at Rocklea and a couple of other places … they're very much lower socio-economic groups, it's semi-industrial.'
EM#2	'In terms of the rising costs of disasters … people have a lot more stuff. So when a disaster strikes and the house gets taken out, people actually have a lot more assets in the house [and] of a higher quality.'
ER#3	'I think the benefits from [the ecosystems approach] – economic and social – will be far greater than anyone's ever estimated. So it's an opportunity just sitting there waiting to happen.'
EM#1	(**on challenges for communities to adapt to flooding**) 'A fair number of communities out there that don't have adequate awareness of their risks and aren't adequately, I suppose, buying in to floodplain management.' Resources and money to … investigate and to do studies and then fund the outcomes … are often scarce.
LG#2	'The current generation doesn't seem to be staying in their job for a long time. When that local knowledge walks out that door, that experience passes away or moves along what that means in a future flood event, if we've got another 15 years or greater [before the next flood] … being far more analytical as opposed to relying on experience I think that's going to be a problem for future flood events.'

5.4.23 Can you suggest any case study opportunities for points you have made? (Question 5)

INS#1 INS#2	'Grantham is probably one we rely on a fair bit [for relocation].'
INS#1	'There are some publicly available submissions on cost-benefit analysis projects with particular councils where they want to put up a flood levee, where there's a measurable premium difference. For example a flood levee being put in at Dirranbandi or Goondiwindi or Saint George, pre flood levee and post flood levee … costings or savings from flood levees around Maitland and Lismore, there's some good examples there.'
INS#2	North Wagga Wagga (for development controls and rebuild provisions).
INS#3	The Emerald and Roma example. I think Brisbane's a good case. It flooded in '74, it flooded in 2011. So every 40 years or so, it has a big flood. What's the council and what's the government doing about that?
UT#1	Places like Winnipeg on the Red River … they actually built a diversion channel around the town. So when the river gets to a certain height, it actually has a huge floodway that bypasses the town, which they've just enlarged lately.
UT#1	Grand Forks floods.
EM#3	**(on levees, perception of risk, refusal to evacuate)** Nathalia is one that a lot of people are doing case studies at the moment about.
EM#1	'A good case study, especially in regards to the education work, our partnership with Melbourne Water. We developed flood emergency plans and also awareness programs for Melbourne. I think that's a good case study to look at. 'The Catchment Management Authority and the Hepburn Council have just recently completed a floodplain risk-management plan for Keswick, which is an interesting one.

	That's a community that was flooded about five different times during 2010, 2011, and [there were] various challenges they faced there. Again, that's a flash flood environment. They're probably two good case studies I would think that come immediately to mind.'
LG#3.1 LG#3.2	An example of flood awareness that failed miserably in Mackay [was] where they used different coloured lids on wheelie bins as a weekly reminder of which flood area you were in. Levee issues – Charleville levees along the Warrego River where flooding from Bradley's Gully caused water to be trapped behind the levee.
FM#2	The really interesting problem we have is storm surge, which has got a very low frequency but potentially a very high catastrophic impact. The classic would be Hervey Bay where, because of the nature of the underwater landscape – Fraser Island poking out, funnelling down towards Hervey Bay – it's an ever-rising sea bed. We get a 3 m storm surge, 3 m high storm surge in a town which is very difficult to evacuate but development goes on there apace. The Gold Coast is even less frequent. But with the increasing intensity … those are potentially catastrophic. Is it possible to manage for it? At the end of the day it might be a 1 in 10 000 probability that it'll hit. But if it happens then we've got mass casualties potentially … they must run those sorts of scenarios over at EMQ.'
ER#1.1	'The Bremer, the Healthy Country one is quite nice, and that's quite well advanced. It's South-East Queensland catchment, SEQ catchments is the regional body that's taken the lead on that, Simon Warner's the chief executive. So that's a very nice little case study that exists.'
ER#1.1	'The resilient floodplains work that the Queensland Reconstruction Authority has done, that's been published and that's on the web.'
ER#1.3	'The swales work. It was a farm in Western Australia; it was actually on the *Gardening Australia* website.'
ER#1.3	'Making Space for Water in the United Kingdom. Yeah, [that] is sort of incorporating risk assessments into planning applications.'

5.5 Questions on communication of results to user groups

5.5.1 What do you think would be the most effective methods of communicating lessons for climate change adaptation and limits to adaptation in your industry? (Question 6)

The intention of this section was to determine how best to communicate the outcomes of this project to end-users. During interviews, the question was phrased using the words 'Part of the project is to communicate results to end-users. What information do you think would be useful to you?' While this question was generally answered, some interviewees also included broad-ranging information requirements that are beyond the scope of this project. These could be considered for future research directions.

What information would be useful to you?

INS#1	'The focus of the industry sits back on the extreme weather rather than climate, so if we can develop a national view towards what the implications are for extreme weather events into the future that's of benefit to us. The sort of loose bands that we have now, and I know that's nobody's fault, that's just how science works, does not leave insurers in a great place to be making firm decisions anywhere out beyond the five year window.'

INS#1	'If we want to start moving into those areas which are currently not covered, so particularly around sea level rise, we need to see national repositories of mapping for that freely available and to a consistent standard and I think we're a decade away from that at least.'
INS#1	'If we want to see changes to how flood insurance is priced, we need the national repository of riverine flood maps to be produced and there's one other piece of information that is a game changer for insurance in the flood environment, and perhaps unsurprisingly that is first-floor height, the liveable floor height. At the moment we don't know that for any property in Australia. So a national repository of property and building information rather than property information would be of great value to a number of industries, including the insurance industry, because then we'd be able to be actually examining the risks to the building, whereas right now our national flood information data is relative to the property.'
INS#2	Ideas about what you think are the best ways of mitigating against the impact of climate change on flooding risk.
INS#3	'A balanced argument of the cross-subsidies versus paying the actual true risk … you could get 27 customers to pay $1000 more, you said, yeah, but they won't be competitive. You won't grow in that business. I think that's probably not a very well understood area. The role of insurance is probably an interesting concept.'
EM#3 (VIC)	I'd just be interested to see what the findings are covering Queensland as well … what are the key elements, all those lesson learned about instilling continuous improvement and how to be a bit more efficient and how can we build the community's resilience to disasters. I'd certainly be interested to [know what the] perception to floods is across … all those different areas [other countries studied by the project] … are there common threads or themes or does it all depend on locality – that would be interesting because I think that we talk about one size doesn't fit all … I'd just be interested to see how others are actually doing community profiling.'
EM#1	'I think a summary of what the key themes of various reviews have been, and I suppose what the key reaction is to those have been by governments and are there implementation plans in place, has there been community acceptance of the recommendations widely picked up through research?'
EM#1	'International examples are important as well.'
LG#3.2	'A copy of your final report and the various ideas from various jurisdictions around what could be done, but I don't think I need anything more than that.'
LG#3.1	'People like yourself have the opportunity to highlight the inefficiencies of giving the states and the local government too much responsibility in some cases and there is an argument to be had for some of this stuff to be done centrally. The challenge of course is getting everyone to agree on how it's going to be done, essentially.'
LG#2	'Other local government areas – do we all think in the same light? Are there things that we all agree upon or are there things that are very varying in opinions? … To review – is there a standard that everyone agrees upon? If not, what are the differences? Then, from there, you'd probably evaluate why not or why? … That's probably the most interesting part that I would like to see – common ground.'
LG#1	Community level information on climate change impacts.
FM#1	'I'd be interested in your report.'
FM#2	'A study which scopes out where those leading-edge topics are, the boundary between current knowledge and policy. They seem to me to be: • We need down-scaled climate models to give us reliable factors to change our 1 in 100. • The proper integration of flood studies into planning scheme [is needed], taking into account climate change factors.

	• We need to account for the residual risk. • We have to establish whether 1 in 100 is even the appropriate thing. Should we actually be properly analysing the residual risk and looking at the cost benefits of "what is the marginal cost of managing for a slightly higher risk"? Given that these actually aren't 100-year investments, does this actually push your risk to a point where it's quite acceptable?' … [Looking at damage curves], there may be a very small cost of going an extra 50 cm, but it increases the resilience of your built form to a whole lot more events. • We have to work out how we can maintain water quality and continue mining production and how we deal with water build-up on mine sites. • What are the gaps in flood mapping? What should Australian property owners have available to them on the internet about a property's risk of flooding? I would say [there should be] a dynamic model where you can dial up a flood event that's been predicted by whoever's doing the prediction for Brisbane to tell you that your house is likely to be in 1.2 m of water. You know dial up Google Earth, go into – and that's possible and not very expensive … providing flood studies that are being done are integrated into it – and it's been done overseas. • Natural assets might be an interesting leading edge, and I think the area of test is how you get the private landowners to have infrastructure on their property and funded for public benefit. That is going to be the mother of all challenges. We can't even riparian vegetation on river banks. • What is the design and work that needs to be undertaken for the most cost-effective transport and road solutions to be funded when things are being rebuilt? • There is definitely a betterment issue with roads that needs someone to work out how we frontload appropriate design and funding cost benefit analysis so that when the funding decision's made, they're making it with confidence. That this has already been assessed.'
FM#3	'I'd certainly be interested in international perspectives on this sort of stuff, and to have a pithy summary: a synthesis of the implications of [the Australian flood reviews], plus the commonality with international experience.'
ER#1.1	'What you're doing is in fact sort of creating an academic frame for the way in which we can think about these things and provide our advice to government.' ['these things' refers to their own work on short-term interventions, long term policy and planning guidelines and policy priorities]
ER#2	'A very concise summary of the outcomes of those flood studies and comparisons. 'With adaptation now there is much more of a need to compare and contrast between different areas and approaches. So your study provides that opportunity to … if you had a few more questions of each of the flood [reviews] you could pull out some points to each of those questions so that was really comparable across those studies. So why was this study performed? Who was involved? What was the approach? What are the key recommendations for different sectors? 'I would be very interested to know who was involved. You could tabulate that probably across the stage pretty easily, couldn't you? Like categorise sectors or types of people and then on each state have a tick or a cross if they were included. 'Having the recommendations from the Australian studies embedded in a list that had recommendations from international projects, that would be fantastic.'
ER#3	'There's a very poor level of understanding of what natural resilience could do, a lot of resistance to change in thinking. So I'd be – I'd be very curious to find out (a) what is

	the level of understanding of some of these issues, and (b) what opportunity is there, or where are the points of influence, that you could have to try and move some of that thinking along?'

How would the information be used?

INS#2	'Our main focus at the moment is lobbying … the problem that we have with lobbying is that we quite often don't have concrete alternatives … we keep saying, "What you're doing is not good enough" … "Okay, what do you suggest we do and how?" Perhaps we haven't come up with too many great ideas yet.'
INS#3	It's always good to have policy positions, to have good debates, good open debates that give an informed decision, you know? A lot of the time, I think if there's a really well-balanced paper, it's good to share around so people can all be on the same page.
EM#1	Forming business cases to seek additional resources [in key areas].
LG#1	'It goes back to that question, "How will climate change affect me?" and it's handpassing that to our community and it's linking it in … and then transferring that into teams like FloodSafe. So what are we doing about this? Okay, we're going around, we're informing you, someone will knock on your door to contact you shortly and put a level on your house so that you better understand the effects of climate change in the event of flooding … rather than having carbon emissions, climate change, that people can't just fob it off because they actually know what it impacts on them at home.'
FM#2	'The useful thing would be to identify areas where adaptation research can actually add value to the policy development process.'
FM#3	'In policy, it would be used by just sort of framing people's thinking … after the NREC Report comes out in August. That will be the critical moment for all this sort of stuff. That's where the big new ideas would be used. That's a matter of finding who's writing that strategy and meeting with them.'

What format would be most useful?

INS#1	'[To present flood maps, property and building information], we use G-NAF as our baseline right across the industry these days, so any format that makes reference back to G-NAF PIDs or full G-NAF coded data, which fields of information after that is able to be absorbed into basically any GIS or any underwriting system that we have our hands on. So we – for example, our flood data [are] all geo-located back to G-NAF, which allows easy translation across a number of different systems.'
INS#2	'If there's actual concrete examples with … case studies. In this particular place, what you could do is this and the other main thing is the cost of doing these things. 'Very simple language … nice, short, pithy sentences. ' A table is always good because people are often pressed for time and they just want to come and see something that's very easy to navigate. Whereas, I often like the case study way of presenting things because you can put it in a context, rather than just kind of abstract ideas … often, when you've kind of got big chunks of text, important points get lost. Case studies and clear sort of tables are probably a nice format to be for business executive types, who don't ever want to read too much. A good executive summary always helps, obviously.'
INS#3	'I'd love to get copies of the report. Case studies would be interesting to see a balanced view.'
UT#1	A chat once the project is completed.
EM#2	Putting it up on a website.
EM#1	'A report with a good, solid executive summary.'
LG#3.2	'A copy of the report … for the academic journals, it might be nice if you were able to

	produce something that was also able to be reprinted with suitable recognition in non-academic journals. And I say that because we do have some communication tools that go out to council and it might be nice to include something … if you're already doing an article for an academic journal it would be really good to see it also appear in the *Australian Journal of Emergency Management* or something like that. Each of the states and territories has a communication tool with [its] councils where it might be a good place to bed a relatively smaller article about "here's the results of our research and some good things for you to think about".
LG#3.1	'[For non-technical journals] smaller words please and lots of pictures.'
FM#2	'I suspect your scope's too broad to find an audience. 'I think trying to do a report across the whole water front will be of limited value because you won't go to the depth that the people in the policy areas are already operating in … a forum of the key experts in a particular area to actually develop the [leading edge] questions and arguments and information requirements to a level of precision that can you provide a product that meets them – I'm a bit at a loss what the product would [be] like.' 'It's really about bringing [in] the people who are potentially grappling with these problems. So who's rewriting SPP 1/03 and what are the information needs that they have in terms of flood studies. It's really getting to those people that are working on the policy development edges and adding value to those things.'
FM#3	'Given the fact that these people don't even read these big inquiry reports, which are supposed to be guiding their business in a statutory sense, what hope have you got of them reading a report, a fat report that you produce? … You should assume that no one is ever going to read your report. 'We've got to produce the reports … But you've got to say, what are the key new ideas, and then go and say, when can they be applied? … Then actually think about how – who you talk to and how you can make it easy for them to start to this, because big ideas are hard work. But having said that, people love the ideas; politicians love them … But the fundamental – there's going to be three or four big new ideas and observations. 'You need to point to places where it has actually worked, somebody has done it well and these are some big ideas and big directions that you can go, if you implement them properly they can work.'
ER#2	'I think like a four-page kind of thing … I'm a big fan of the way CSIRO does their communications from all the different levels, the technical reports and the full scientific reports and then maybe a 16-page executive summary for intermediately busy people and then the fact sheets. 'It would be great if you could manage to get it down to some areas that could be tabulated so that you could really easily compare between them. I would also be interested in a pretty straightforward catalogue of recommendations between all of them.'

5.6 Analysis

In some areas there was remarkably strong consensus. This includes views about the adequacy of current mitigation investment and some aspects of disaster relief and recovery arrangements, such as betterment provisions. Other measures, such as development controls, received strong agreement by most, but not all. Some important

issues were raised, even by proponents of this approach – something that it will be necessary to address if this measure is to be used to its full potential. Some interviewees promoted measures of which many people have little in-depth understanding – in particular, ecosystem approaches to flood management and methods of implementing them, such as payment for ecological services (PES). The views expressed about these approaches highlight both the potential people see in them for application in Australia and the barriers that would need to be overcome. Some of the key issues that have emerged are discussed below.

5.6.1 Development planning

Development planning is a key adaptation measure identified by most interviewees. Many interviewees observed that recently approved developments had been inundated. This was often blamed on short-term views in the development process and long periods of drought in between floods. Some suggested that climate change would only exacerbate this, as periods of drought are expected to become longer. Catchment management authorities were seen to have the necessary long-term view, though in some states they were severely under-resourced.

A significant issue raised by one interviewee (EM#2) was the need to provide affordable accommodation for lower socio-economic groups. This is a significant competing priority that inhibits the incorporation of flood considerations into development decisions. The issue was lightly touched upon in the final Queensland Inquiry (p. 138), when it discussed reduced flood controls in satellite legislation to meet affordable housing objectives. This issue interconnects with another significant measure: community resilience.

The interviewee argued that flood is a 'discriminatory hazard'. It is the poorer people who are located in flood prone areas because affordable housing is often located in undesirable semi-industrial areas. This is also supported by the Queensland Inquiry, which notes that industrial areas are commonly located in more flood-prone land for economic reasons because it is cheap: 'if industrial development were to be restricted in these areas, the economic disadvantages might outweigh the benefits' (Queensland Inquiry final report, p. 156). In a sense, the very predictability of a flood endangers those least likely to be able to cope with it.

Other vulnerable groups are also more likely to live in flood prone areas. In an example provided by the final Queensland Inquiry, an aged care facility was built on land that was zoned for 'light industrial' development. Provisions for assessing some types of 'community infrastructure', such as aged care facilities, have inferior provisions for assessing and addressing flood risk (pp. 149–150, 174). Another interviewee, EM#3, further noted the lower socio-economic status of many of the people flooded in rural areas.

The provision of cheap (but risky) residential sites to disadvantaged groups with lower socio-economic status, or to the elderly in the form of retirement homes, only increases their long-term vulnerability to climate change. Climate change studies suggest that future flooding risks to disadvantaged groups 'would increase by factors of three to 20 – significant sections of the population could be blighted' (Galloway 2009, p. 6).

If the government determines that affordable housing is needed, it perhaps needs to weigh up the most cost-effective and appropriate way of achieving this. Subsidising the long-term costs of affordable housing through increased expenditure on disaster relief may not prove to be the most cost-effective solution (see comments by INS#2 in the 'cost-effectiveness' section). It is not consistent with the 'community resilience' approach. Neither is it a just solution in terms of psychological impacts to which people will be exposed, which were described by many of the interviewees who had witnessed them.

Other significant barriers to improved development planning identified by interviewees include:

- population pressure
- the lack of assessment of existing development assessment processes that look at applications on a local scale, and the compounded effects of development on a catchment scale
- environmental objectives (reducing the urban 'footprint' via infill) decreasing the availability and affordability of flood-free land within urban areas
- limited availability or high cost of developing flood-free land beyond existing township boundaries
- a lack of responsibility, accountability and consequences for those who make land development decisions
- vulnerability to legal challenge when denying development applications – which, in one case cited by an interviewee (ER#3), consumed the council's entire budget
- the lack of resources to provide compensation for reduced land value or rejection of development approvals due to rezoning
- uncertainties associated with the identification of the 1:100 flood line and climate change
- inadequate requirements to incorporate flood studies into planning schemes.

There are many issues that need to be worked through in terms of facilitating the incorporation of flood studies into planning schemes and consequent rezoning. Best-practice processes would need to be developed, supported by legislative provisions (such as strengthening Queensland's state planning policy SPP 1/03). Should these processes include compensation (and most interviewees agreed that compensation was appropriate), resources would need to be made available for compensating people for its drop in market value and for people who had purchased land in the expectation of being able to develop it. The expenses involved in compensation and legal action appear to be a significant issue for local governments. If they are expected to revise development controls in line with existing and future flood studies, there will need to be the financial and procedural support to enable them to do so.

Greater financial accountability on the part of planning decision-makers was suggested by some. While this was often seen to be a local government issue, all three levels of government were implicated in bad development decisions by different interviewees, including the federal government through its economic stimulus package. State governments were often seen to be overriding good decisions by councils. If local government, as the government level primarily responsible for planning decisions, is to be held accountable for its past development planning mistakes, it is even more important to ensure that it has the capacity to easily revise planning schemes.

One interesting idea was for there to be oversight by an independent authority to ensure flood studies are incorporated into planning schemes, and that an expanded 'all hazards' emergency management agency might be an appropriate place to house such a function. This is because emergency managers are the people who have to deal with the consequences of bad planning decisions on the ground, and whose personnel are put at risk by such decisions during disaster response.

Climate change uncertainty was another issue that dogged development. One interviewee was very concerned that, although flooding was more predictable than any other hazard, existing knowledge about flood-prone areas – commonly conveyed in terms of likelihood (1:100 year flood lines) – may be thrown out completely by people trying to capitalise on future uncertainty. Some suggested that approaches should focus more on appropriate strategies to reduce consequence, rather than likelihood. Others suggested that using much more conservative likelihood values would be more appropriate to address uncertainty. However, this was very much a case-by-case basis, as in some areas flooding is shallow and slow moving, and it would be relatively cheap

to require that floor levels of new development be increased by the few centimetres it would take to accommodate a flood of a significantly lower likelihood.

While downscaling climate change information to catchment level was seen as useful for awareness of potential scenarios, ER#2 suggested it had limited use in decision-making, as uncertainties simply compounded when models were reduced to the catchment scale. States like Queensland are considering applying a 'climate change factor' to flooding in planning schemes to accommodate climate change uncertainties. While LG#3.1 and LG#3.2 felt the factor had a somewhat loose scientific basis, they had not heard any dissatisfaction expressed concerning its use.

The understanding of past flood events was seen as very useful by ecosystem researchers in placing limits on possible maximum flood extent, which is useful in terms of awareness of potential flood extent if flooding is expected to increase in intensity. Geomorphology was also important in terms of understanding the movement of rivers within their floodplains. Without this understanding, development could inadvertently be placed on a river channel that could re-establish in a future flood.

Some interviewees made the point of how costly it is to reverse bad planning decisions in terms of buyback or compensation to reverse approvals, or potential liability where approval is given despite there being a known risk according to flood studies. It is much cheaper to ensure appropriate planning in the first place.

5.6.2 Community resilience

Community resilience is currently a popular approach in Australia and overseas, in countries like the United States. In theory, community resilience addresses all stages of emergency management, including prevention–preparation–response–recovery (PPRR). However, most interviewees who discussed community resilience focused on the availability of flood information to enable improved risk awareness, leading to greater personal responsibility.

Availability of flood information was seen as a major impediment to flood risk awareness, and no interviewee proposed that access to flood information should be limited. Many interviewees reported difficulties in accessing existing flood information that was necessary to perform their work, including ER#2 for research purposes and UT#1 for water infrastructure. The insurance industry has found that this so important for its business that it has developed its own database of information, and the utility interviewed was attempting to do the same. Interviewees from all sectors wanted information to be made available for improving community awareness, resilience and/or community support for mitigation measures. Information availability is currently being addressed to some extent by federal initiatives, though flood study methodology and standards are variable, which is an issue that affects the usability of data.

Methods of increasing risk awareness were varied. Flood markers, information in meter boxes, on land titles, inclusion in planning schemes, the Victorian FloodSafe program, workplace courses, community forums and 'resilience committees' were all methods that were seen as useful.

Awareness is an important precursor to all stages of PPRR, but it does not necessarily translate into action. As seen in the 'development planning' section, many of those most affected are low socio-economic groups, or the elderly who have limited ability to implement PPRR. Even if people are provided with information prior to purchase, they may not have the financial resources to purchase or rent in a safe area. People with less money do not necessarily worry about a threat that may not happen for 20 years, when the immediate need is to have a roof over their heads. It is debatable whether purchasing under these circumstances could be described as a personal choice to accept the risk. If there is a lack of affordable alternatives, there is no choice, and responsibility cannot be placed on people forced into this situation.

Vulnerable groups also have more limited resources to increase their resilience by purchasing insurance, building to more rigorous standards, retrofitting their homes or relocating. People may not have even the facilities to move their belongings out of harm's way if they only have a single-storey house. Moreover, people who purchase a house in a flood-risk area, while they may be made aware of the risk, may not have an in-depth understanding of the long-term financial implications of the decision. There are also significant cultural and attitudinal barriers that affect resilience and people's willingness to accept responsibility, described in Section 5.4.22. Even where effort is put into risk awareness, there are no guarantees that it will work, as individuals can make mistakes and do not always behave rationally when disaster strikes. Capacity issues such as these were raised by many interviewees, including by one interviewee who had specialised expertise in the community resilience area.

For the reasons outlined above, if community resilience is narrowly interpreted as 'community risk awareness' in order to place responsibility for risks onto individuals, it is a misuse of the word 'resilience'. In this context, community resilience merely reduces residual risks that would not have occurred had prevention measures been adequate. Awareness alone is not effective unless people are empowered to do something about it, and if this method is to be relied upon, the issues surrounding disadvantaged groups and attitudinal barriers have to be addressed.

Despite issues with over relying on this approach, investment in community resilience has significant benefits. In the context of climate change, improved self-reliance can only be a benefit if flood events become more severe, stretching the capacity of response personnel. It is a key measure to address residual risks for existing development. It can help to inform those with the necessary financial resources about purchasing, building or retrofitting in a way that is appropriate for their area. Everyone, regardless of status, can be informed about the risks in their area and what can be done by way of preparation and response, including emergency kits, knowledge of evacuation provisions and having strategies in place should an event happen. It also has the potential to foster changes in attitudes. Another advantage is that community resilience is a relatively cheap measure, and it is appealing for corporate sponsors who wish to raise their profile and reputation in the community.

A crucial factor to community resilience is that it needs to be ongoing due to population movements and the forgetfulness of people between floods. If permanent arrangements are not in place to implement awareness, it is likely that much of the useful effort in this area will be wasted.

5.6.3 Relocation and buybacks

There are two significant buyback schemes that took place after the recent flood events, one in the Lower Loddon in Victoria and one in Grantham in Queensland. In the Victorian example, the government is looking at recouping some of the costs by resale in a way that restricts land use to more flood-compatible farming practices. Although there were many social issues to work through, the program promises to improve the long-term resilience of the area. At Grantham, there was the added impetus of many lives having been lost and the Queensland Reconstruction Authority was instrumental in implementing this approach. While not all residents wished to relocate to the unattractive and windy site that was selected as the alternative, this scheme is also generally lauded as a success for improving long-term resilience.

There tended to be agreement by interviewees about the effectiveness of relocation options, but opinions tended to vary more widely about the advisability of using them. Most felt relocation was an expensive option, and that implementation was currently ad hoc. Some were strongly in favour and suggested that while it was expensive, it was more a matter of funding priorities rather than of the money not being there.

Looking at insurance pricing, as explained by INS#3, it is evident that the greatest cost is incurred for development located in areas of highest flood frequency. Insuring for a 1 in 20

year event may comprise $10 000 per year of your annual insurance premium ($200 000 value property damage divided by 20 years), whereas insuring for a 1 in 100 year event would be much lower in terms of annual cost. Evidently the costs are greater the more frequently flooded you are, so relocation is most cost-effective for the most frequently flooded areas.

Covenants and preferential purchase orders were suggestions for implementing a more long-term strategy of buybacks or land use changes. Some suggested funding mechanisms that may be required if this were to be implemented, such as a pre-approved bucket of funding so that opportunities to purchase flood-prone properties when they come on the market were not lost due to lengthy approvals processes. In the case of the Lower Loddon, buybacks were cleverly funded by linking in with other government programs.

It is evident that relocation or changing land use is an effective way of improving long-term resilience. However, it is equally evident that preventing inappropriate development is a much cheaper and simpler option than buying land back or placing development restrictions on land use after it has been released.

5.6.4 Structural approaches

There was support for levees in terms of protecting existing development and individual buildings through ring levees. At least in Victoria and New South Wales, interviewees indicated that town levees are mostly well regulated and maintained. However, considerable reservations were expressed about catchment-scale rural levees, including pseudo-levees. The problems with structural approaches include increased flood heights and energy, the initial expense and ongoing maintenance costs, the need for rigorous regulation, their propensity to prolong flooding by preventing drainage, their failure to prevent flooding from unexpected sources and their potential for breaching. In common with ecosystem approaches, the use of levees also requires catchment-scale modelling and implementation to prevent flood problems from being transferred to others. While these measures have their place, support for such measures by interviewees was generally muted.

5.6.5 Ecosystems approaches

Ecosystem approaches to flood mitigation are probably the least generally understood measures. Unsurprisingly, ecosystem researchers and floodplain managers had an excellent understanding of these measures but other sectors only had limited understanding and many reservations. Ecosystem researchers suggest the main reason for lack of understanding about this approach could be due to segregation between traditional flood management and natural resource management disciplines. However, ecosystem approaches are widely used overseas, and have a great deal of potential to address some of Australia's most significant flood issues.

One issue identified by a number of interviewees (including from other sectors) was floodwater velocity, or energy. This aspect of flooding had little coverage in the reviews but was recognised by many interviewees as causing some of the most expensive damage, primarily to infrastructure such as roads, bridges and railways, but also in terms of erosion and loss of farmland, reduced water quality and long-term reductions in storage capacity of dams due to siltation. This issue was covered by the ENRC Inquiry report, which was released after the interviews took place.

Ecosystem researchers have identified methods to reduce these problems. Research suggests that work needs to be done primarily in the upper catchment to impede water. Thus, rather than clearing and straightening water channels, vegetation actually needs to be encouraged to grow inside them and for water to spill over onto the floodplain. This is a completely revolutionary idea that strongly contrasts with current practices and community views that are described in Section 5.4.19, and in the ENRC Inquiry (pp. 114–18). Upper catchments would be encouraged to flood and hold water temporarily in wetlands or detention basins, then gradually release it back into the system.

This approach has many benefits besides reducing damages. It would delay flooding downstream, and thus increase warning times and potentially reduce damages and casualties from flash flooding. It would also reduce flood peaks and, crucially, decrease the power of floodwaters in the middle and lower catchments. Another benefit is that it could allow aquifer recharge – a significant benefit that could help address increasing severity of climate change drought. By contrast, channel straightening, vegetation removal and floodplain levees to protect rural land were all seen as being counter-productive in that they increased velocity and transferred flood problems downstream or across to neighbouring properties.

Interviews with ecosystem researchers indicated strong awareness that the most productive farmland was in the middle catchment, and thus little could be done there to reduce the power of the flow. Suitable interventions in middle catchments could include bank stabilisation with riparian vegetation. By contrast, land in upper catchments was generally of lower value and there was scope to ensure compatible dryland grazing uses and payment to property owners for the inconvenience of occasional flooding. The general feeling was that it was important for land to remain in production, but to ensure that production was compatible, through extension activities and through possible payment for ecological services (PES) mechanisms.

Tools have been developed to determine what locations, interventions and the area of land that needs to be revegetated or managed appropriately. However, such work is area specific cannot be interpolated more generally. A business case done to apply ecosystem approaches to reducing sedimentation in the Moreton Bay area suggests that 70% of the sediment is coming from 30% of the region, so it is possible to target activities to specific localities. This example also suggests that the activity would be cost-effective in terms of water quality and supply, as well as having side benefits for fisheries and wildlife. The value of avoided flood damage costs was not included in this study, though the researcher affirmed this could be done.

One of the biggest challenges is that implementation of ecosystem approaches requires flood studies, modelling, planning and implementation on a catchment scale, rather than on the individual town or locality scale, which is currently the norm. There seem to be few effective mechanisms for ensuring a catchment approach. It was definitely seen as being beyond the scope of local councils or communities. Implementing approaches like this would need to be led from a state level, and would need to involve all players. Catchment management authorities that operate in Victoria through the state government were seen as being a possible vehicle for facilitating this. However they would need to be adequately resourced. The Moreton Bay example above was carried out under the Healthy Waterways Partnership.

Payment for ecological services was discussed with interviewees of all different sectors to determine their opinions on its feasibility, acceptability and potential barriers. Many reservations were expressed, possibly as a consequence of unfamiliarity with this mechanism. Issues discussed included who would pay, how much they would pay, how to determine the amount of land needed to provide a given benefit for a given downstream locality and how payment could be made. Some issues were raised in terms of dismantling levees that could affect neighbouring properties and reservations about taking farmland out of production. One interviewee was of the view that PES was a state government responsibility. Another suggested it could be paid for through water supply charges. Certainly it is an approach that has the potential to facilitate land use management practices that benefit entire catchments and it therefore serious consideration should be given to how such schemes could be implemented.

5.6.6 Response issues

Responders tended to support the outcomes of the flood reviews. One interviewee, EM#1, suggested that overall emergency strategy, prevention and preparation were much more important to prioritise than command and control arrangements. The biggest

issues for flood responders tended to be flood warnings, particularly with regards to flash flooding, community resilience (discussed above), local flood planning, evacuation and volunteer management.

Many interviewees were particularly dissatisfied with the adequacy of evacuation planning in the recent floods. Evacuation issues included unsuitable facilities for flood (they were suitable for fire) and unsuitable for cyclone (which can and did coincide with the flood). As part of improved planning, trigger points for evacuation and for knowing when it was safe to return were one measure suggested.

Flash flooding was seen as a significant issue for climate change scenarios, as increasing rain intensities are likely to increase this problem. Measures to improve warning for flash flood were supported, including recommendations from the Comrie review and the BoM review. Improving understanding about flash flood areas was suggested by one interviewee as a research need.

A key issue for emergency response was funding arrangements. Resourcing of volunteers was seen as inadequate, and the South Australian model of funding emergency services through rates and vehicle registrations was seen as equitable in that it spread costs evenly across the community, compared with some models that require a surcharge to be paid by those who purchase insurance. Mutual aid agreements have proved to be extremely effective in the urban utilities sector.

5.6.7 Mitigation funding, disaster relief and betterment

There was some high praise given in terms of the adequacy of amounts, and in Victoria high praise for payment mechanisms that used a schedule of rates contract. In terms of delivery of recovery, community development officers were a significant element, but they needed to be deployed early and over a long period of time. The Queensland Reconstruction Authority, while having some issues, was generally seen as being very successful in centralising and sustaining recovery effort, attracting resources and in implementing approaches – such as relocation – that might otherwise have been impossible.

These recovery successes contrast with a widespread dissatisfaction over the lack of mitigation and betterment funding, and over disincentives to mitigate as a consequence of over-generous disaster relief and recovery funding (see Sections 5.4.19, 5.4.21 and Question 3b in Section 5.3).

Interviewees noted that betterment was almost impossible to obtain, and only one example was able to be provided, of an Aboriginal community that managed to hold out long enough, isolated without a road, until approval could be obtained. Interviewees felt that the billions spent on repairing infrastructure would not increase resilience but would only last until the next flood event. Many were highly concerned that the Commonwealth, by investing so much in recovery funding, was also creating disincentives for states and local governments to apply adequate preventative measures, such as improved development planning. Disapproval was also expressed about the untargeted nature of individual payments that did little to help those most severely affected, and that could have been used to assist rebuilds. Individual cash payments have been similarly criticised in the United States (see case study in Section 6.3).

A significant concern was the lack of balance between federal disaster-mitigation funding and relief and recovery funding. Some interviewees noted the relative cost-effectiveness of spending on mitigation, in terms of reducing response and recovery costs. The federal government's National Partnership Agreement on Natural Disaster Resilience provides 'for collaboration on natural disaster mitigation activities', and it is meant to spend approximately $30 million to be divided between all hazards across all states annually (Attorney-General's Department 2012b). As one interviewee exclaimed, this is barely enough to fund one flood levee. While annual state implementation plans contain amounts that roughly tally with this amount, actual amounts reported in the Attorney-

General's Department annual reports do not appear to match planned expenditure figures. Inquiries to clarify actual funding figures and a clearer breakdown of activities have so far not yielded any response.

According to the agreement's interpretation, 'resilience', funded through the agreement, includes all stages of PPRR. Not all interviewees seemed to have the same understanding of 'mitigation activities' as including all stages of PPRR. Mitigation was generally seen as being more at the proactive prevention end of the spectrum. It therefore seems somewhat problematic to describe this agreement as the Commonwealth's contribution to disaster 'mitigation' funding.

A perusal of state implementation plans developed under the National Partnership Agreement on Natural Disaster Resilience reveals that, among other things, it funds community resilience. As it is a 'resilience' agreement, this is not surprising. It is hard to determine, by reading state implementation plans, what activities are classified as 'community resilience', but it seems evident that awareness-raising, self-reliance and individual responsibility are key ingredients. The issues surrounding this narrow approach to community resilience are discussed in Section 5.6.2.

While UT#1 noted that it was cheaper in the long run to build mitigation into design in the first instance, flood disasters provide a window of opportunity to rebuild to more resilient standards. The main issue around this was the timeframe needed to conduct cost-benefit analysis prior to obtaining approval. When infrastructure is damaged, it needs to be restored as soon as possible, and cannot wait for such processes. Some suggested pre-approval. One local government interviewee (LG#2) suggested that a more comprehensive betterment scheme was needed. Interviewee FM#2 suggested that cost benefit research into betterment might help decision-makers.

An issue with pre-approval of betterment identified by one local government interviewee was that any infrastructure identified as deficient would become subject to duty of care, and would need to be included on a schedule of works. This might make it ineligible for betterment. Thus current processes actively work against forward planning and a strategic approach to betterment, which is not helpful if the government wishes to build resilience.

5.6.8 Insurance

Currently, insurers do not tend to incorporate climate change into premium pricing due to a short term horizon for setting premiums; the perception that natural climate variability in Australia is more significant; and uncertainty about the impact of climate change at the property level. The insurance industry may therefore have limited ability to factor in climate change due to risks that the policies of those companies that do may become uncompetitive compared with companies that don't. However, this means there is a risk that insurance companies may be hit with increasing losses if flood frequency and severity changes. If flood studies include climate change risks, it is more likely that insurers will incorporate these risks.

There are opportunities for new insurance products that specifically address climate change, but these are not currently available in Australia. Some, such as a 'life insurance' style policy to address sea level rise, would need significant development to get beyond concept stage.

There is, however, significant potential for the insurance industry to decrease its exposure to increasing flood damages by becoming more proactive in mitigation. It already lobbies government to increase funding for mitigation. It has also put pressure on individual communities to improve development planning and put in place structural mitigation measures to reduce risk, offering lower premiums as an incentive. If insurers are to do this on a regular basis, they will need to be very careful about the measures they advocate as studies of measures elsewhere in this report caution that some

measures, particularly structural mitigation, can have significant adverse affects and can increase future risks if not properly implemented.

Another option being considered is a more proactive involvement in the repair and rebuild process when property is damaged. As part of the assessment process, improvements to property that cost no extra would automatically be incorporated, and there would be provision of information and advice to clients about improvements that would cost extra.

There is also potential for additional insurance products, such as extra coverage that would enable improved design of repairs and rebuilds, use of improved materials, or to assist relocation in the event of a property being significantly damaged. To enable this – particularly for people in low socio-economic areas who have less ability to pay for improvements – insurers could partner with government in reconstruction processes to ensure grants are available for people to make up any shortfalls for expenses in excess of the insured amount. Such measures could well reduce the insurance industry's longer term exposure to flood damage, which would be of benefit for both current and future risks.

5.6.9 Conclusion

A broad agreement was evident for some issues, such a support for improved development planning, asset and building design and the need for a significant increase in expenditure on disaster mitigation and betterment to increase future resilience. Potentially, insurance could facilitate the implementation of both mitigation and betterment of individual properties or at the community level. Current disaster relief and recovery funding mechanisms were seen as acting as a disincentive to implementing disaster prevention.

Ecosystem approaches have great potential to reduce flood damages in terms of costs to infrastructure, and have numerous other co-benefits that could benefit climate change drought scenarios, as well as flood. Initial indications are that this is a cost-effective approach, but it would require more complex and inclusive planning on a catchment scale. Due to general unfamiliarity with this approach and the science underlying it, it would also require a large investment in education. Funding ecosystem approaches could be achieved through PES, but implementation of PES may require further investigation.

Community resilience is useful in that it increases awareness and preparedness, and it could also engender a greater sense of responsibility. However, it will need to address capacity issues for disadvantaged groups for it to reach its full potential. Measures that only found limited support included relocation (on the grounds of expense) and structural measures, particularly large-scale floodplain levees.

6 OVERSEAS STUDIES

6.1 China

6.1.1 The resources selected

The primary references for China were selected by the research team and by collaborating researcher Professor Guangchun Lei of Beijing Forestry University, China. The references selected focus on flood control in the Yangtze River Basin, China's largest river basin, where innovative programs have recently been carried out that address increased flood risk. The approach taken increases the capacity of the landscape to accommodate larger floods, while simultaneously improving water quality, wildlife and rural incomes. A consideration in the selection of these resources was their availability in English.

6.1.2 Chinese approaches to flood management

The Chinese have perhaps the longest records of flooding in the world. Over the past 2000 years, more than 200 major flooding events have been recorded in the Yangtze River, including the flooding disasters in 1860, 1870, 1931, 1935, 1954, 1991, 1996, 1998 and 2010. Of these, the 1860 and 1870 flood events marked record high discharge rates (100 000 m^3/s and 110 000 m^3/s). Flooding in 1935 killed more than 140 000 people, whereas the 1998 flooding event caused the highest economic loss (3% of China's GDP in 1998).

The frequency of flooding in the Yangzte River has been increasing and the annual maximum water level is becoming higher, particularly in its middle reaches (Zhang et al. 2006, p. 263). According to Wang (2004), from the mid-seventeenth century to early twentieth century, the Yangtze flooded about once a decade. This increased to once in every six years during the first half of the twentieth century, and during the 1980s the frequency of large floods was every two years. In the 1990s, flood frequency further increased, culminating in a major flood event in 1998 (Wang 2004, p. 166).

Traditionally, the Chinese have relied highly on structural approaches to mitigating floods. While this continues to be of key importance, soft measures such as improved development planning and land management have become increasingly important in flood mitigation. Considerable effort is also put into flood preparation, such as flood forecasting, warning and information systems to support decision-making (Zhang 2004).

Review process

The disastrous 1998 flooding triggered intense public debate on flood management strategies. The 1998 flooding lasted for one month, which was far longer than any previous flooding. The duration of the flood response effort, led by top political leaders with participation of whole communities, proved extremely useful for contemplating future strategies. After the flooding, different interest groups, academic societies and government agencies, as well as the legislative authority and the National People's Congress, conducted a series of reviews on existing flood control strategies. Recommendations from different ministries, including water, land care, environment, forestry, agriculture, science and technology, education, development and reform, as well as meteorological administrations and the Chinese Academy of Sciences, were submitted to the State Council. This led to the development of the '32 Character Policy'.[7] The policy presents an innovative approach to flood management that includes revegetation of upper catchments, as well as a combination of floodplain and wetland restoration with dredging and dyke management, and relocation of people who live in

[7] Consisting of eight strategies, each expressed in four characters.

regions vulnerable to flooding for adaptation to climate change flooding (Guangchun Lei, pers. com.). The policy was followed by an amendment to China's Water Law in 2002 to include a strategy of integrated river basin management (Te Boekhorst et al.. 2010).

The '32 Character Policy' was implemented via a package of projects. The total budget was US$3.2 billion (20 billion yuan) for floodplain management, and a package of US$30 billion (192 billion yuan) was provided for upstream forest protection (logging-ban), and rehabilitation (conversion of sloping farm land to forests) (Guangchun Lei, pers. com.).

Climate change

Climate change is expected to exacerbate flooding in the Yangtze River Basin. While average precipitation is expected to remain the same, the variability between years is expected to increase, resulting in greater likelihood of extreme weather events (Yu et al. 2009, p. 243; Zhang et al. 2006, pp. 255–6; WWF-China Programme Office 2009; Government of China 2007, pp. 4–6, 17–18).

Understanding of the risks of climate change has been growing in China, and recently a large-scale report was produced for climate change adaptation in the Yangtze River Basin. The report involved experts from the Chinese Academy of Sciences (CAS), China Meteorological Administration and Fudan University, as well as WWF-China, and it outlined key vulnerabilities for the Yangtze River Basin and strategies to address them. Strategies include reducing community and infrastructure vulnerability; adapting agricultural systems; the promotion of integrated river basin management; wetland restoration; protection of natural forests and headwaters, including permafrost and grasslands; and low carbon development (WWF-China Programme Office 2009). The government responded to the report by reviewing national mitigation and adaptation strategies. The measures promoted by the report have also been included as climate change adaptation measures in China's National Climate Change Program (Government of China 2007, pp. 44–5, 48–50). A new strategy, including a flood-management component, is expected to be promulgated in 2012 (Guangchun Lei, pers. com.).

A recent study by Shi et al. (2007) on the channel morphology of the Yangtze suggests that an increase in flood discharge may have a disproportionate effect on flooding in some areas. The Tianjiazhen reach of the middle Yangtze has an area of narrow channel width, which allows floods of < 50 000m^3s^{-1} to comfortably flow through within 24 hours. However, if the discharge is greater, water backs up increasing the depth and duration of peak flood levels upstream. During the 1998 floods, this resulted in a flood peak upstream from the bottleneck that exceeded 20 days, impacting on the densely populated cities of Wuhan and Juijiang (Shi et al. 2007, p. 8). Should climate change increase the intensity and duration of precipitation, severe floods that exceed the 50 000m^3s^{-1} threshold are likely to become frequent, though projects such as the Three Gorges Dam can be expected to mitigate at least to the level of a 1:100 year flood event (Chen 2010).

Engineering measures

Flood control in China traditionally has had a very strong focus on engineering methods. Dam building to control flooding became increasingly important from the 1950s under Mao, and recent projects such as the Gezhouba Dam and the Three Gorges Dam, along with tens of thousands of other reservoirs, have been built partly to control flooding of the Yangtze. The Three Gorges Dam was successful in controlling the 2010 floods, which had a peak flow of 70 000 m^3s (considerably larger than 50 000 m^3s in the 1998 floods). However, some are questioning the dam's long-term effectiveness for flood control. The dam is only designed to withstand 100 000 m^3s, and if the flow exceeds 122 000 m^3s, the safety of the structure will be at risk (Chen 2010, pp. 10–11). Risks for

dam management are complex, since many major dams have been built upstream of Three Gorges Dam, primarily for hydropower generation (Guangchun Lei, pers. com.).

Like Australia, China has experienced tensions between the flood-storage and supply functions of dams, with users from irrigation and hydro-power sectors calling for flexible operational practices, enabling them to increase water levels in dams towards the end of the wet season (Zhang 2004, p. 5). Another proposal is to remove flood control capacity from existing and planned Yangtze dams to generate more hydropower in return for funding more floodplain restoration. Restored floodplains would take over the function of floodwater storage and conveyance while compatible land use enables it to continue to generate agricultural income (Opperman et al. 2009).

Levee building is a flood-protection measure that has been used in China for centuries. Levees can be as high as 20–37 m, resulting in massive consequences if they fail, and high maintenance costs that are sometimes beyond local capacity to meet (Pittock & Xu 2011, pp. 3, 6). Levees generally are sufficient to accommodate floods of a 10- to 30-year frequency. However, larger floods need to be diverted to detention basins (Wang 2005). In the case of severe floods, levees of ungated detention basins are sometimes blown up to let in water to prevent more catastrophic flooding elsewhere. This is a last resort as, due to population pressures, detention basins are inhabited and 'compensation laws and flood insurance in China are still embryonic' (Wang 2005). Under current Chinese policy, structural measures such as dams, levees and channel regulation continue to play an important role in flood protection, and the reinforcement of key levees is among the strategies of the 32 Character Policy.

Levees have caused several problems in China. They restrict river channel capacity, thereby causing higher flood levels; they also increase siltation of the floodplain and river channels within the levees (Yin & Li 2001, p. 106; Zhang et al. 2006, p. 263). These levees are elevated above the floodplain, and when they fail – as some did in 1998 – they can cause large-scale death and economic damage.

The way in which levees contribute to siltation is illustrated by the Great Jinjiang Levee, one of the earliest important levees in the Yangtze River Basin, completed in 1548. This levee cut the connectivity between the Yangtze and some of its lakes. Four gaps have since formed, enabling discharge south into Dongting Lake (Yin & Li 2001, p. 107). Over four centuries, the levee has restricted the area available for water to spread and for sediment to be deposited, resulting in the southern floodplain being several metres higher than the northern plain. It has also increased siltation of Dongting Lake, the riverbed and banks, reducing their water-holding and discharge capacity. The completion of Three Gorges Dam has resulted in the sediment being trapped in its reservoir, and this has caused further problems, with erosion of the Yangtze River bed below the dam. This has stranded and desiccated key floodplain wetlands and lakes.

Land use and floodplain restoration

Increasing flood frequency in the Yangtze River Basin has been attributed largely to inappropriate land management, as it was observed that the flood discharge of the 1998 floods was lower than the 1954 flood, while the peak water level was higher (Yin & Li 2001, p. 105).[8] Recent land use practices, such as deforestation, land reclamation and structural flood protection measures, such as levees, have all increased China's vulnerability to flooding. According to Zhang, 1100 lakes along the Yangtze River have been eliminated in the past 40 years by land reclamation, enormously reducing the ability of the river basin to store and retain floods and increasing the flood flow in the river channels. This has been driven by population pressure and economic growth (Zhang 2004, p. 4).

[8] It should also be noted that the Jingjiang basin, with a storage capacity of 5.4 billion m^3 was used in 1954 but was not used in the 1998 floods (Wang 2005).

Recognition of the contribution of land management to increased flood risk has prompted a major strengthening of flood mitigation measures, including policy, legislation and public education into the importance of environmental protection. While structural measures continue to play an important role, current approaches to address climate change also seek to increase adaptive capacity by improving land management (Zhang et al. 2006, p. 255). This contrasts quite significantly with Australian reviews, which generally pay scant attention to the impact of issues such as land management on flooding.

Land-use activities believed to have increased flood risk in the Yangtze River Basin include loss of vegetation, including deforestation and reclamation of wetlands for agriculture.

Loss of vegetation

Deforestation caused by logging and conversion of forests for agriculture and overgrazing has reduced the water-retaining capacity of the soil and increased erosion, leading to sedimentation downstream and degradation of hydroelectric and irrigation schemes (Wang 2004, pp. 162–5; Pittock & Xu 2011, p. 4; Yin & Li 2001, p. 106). These problems are particularly significant in the upper reaches. Deforestation can also be responsible for fatal mudslides – for example, in the 2010 Yangtze floods (Chen 2010).

Erosion in the upper catchment causes siltation of riverbeds and lakes, reducing their capacity to store water. Yin and Li (2001) report a strong correlation between vegetation cover and erosion, with forest cover in the Yangtze drainage area reducing by half between 1957 and 1986, while land subject to erosion doubled (p. 106). This finding has also been backed up by palaeological studies of sediment discharge in the Yangtze and Yellow Rivers, which found that prior to 2000 years ago, sediment discharge was about 20% of current rates. At around 2000 BP, human activities such as deforestation and agriculture caused dramatic increases in sediment discharge (Saito et al. 2001).

Deforestation in the upper and middle reaches of the rivers and plateau regions, and loss of floodplain wetlands, exacerbates erosion and flooding, and also reduces water quality. Table 6.1 shows the impacts of flooding in the Yangtze River catchment since 1931 (original source located in Yangtze River Water Resource Commission Yangtze River Yearbooks 2000–03).

Table 6.1: The impacts of flooding in the Yangtze River catchment since 1931

Year of flooding	Affected population (in millions)	Affected cultivated area (km^2)	Casualties	Damaged houses	Economic losses (US$m)
1931	28.55	33 933	145 000	1 796 000	22.99
1935	10.03	15 093	142 000	406 000	-
1949	8.1	18 140	5 700	452 000	121.9
1954	18.81	31 700	33 000	4 300 000	-
1991	50	130 000	3 074	4 980 000	3 658.50
1995	92.12	64 721	1 085	785 000	6 903.10
1996	70.81	46 093	2 700	324 100	8 536.60
1998	200	90 000	4 150	6 850 000	20 000
1999	290	218 000	3 000	17 000 000	24 900
2002	91	732 198	917	588 330	4 998

Land reclamation

Construction of polders for agriculture in and around lakes and detention basins, and a lack of connection of lakes and wetlands with the Yangtze have reduced the landscape's water-holding capacity (Yin & Li 2001, p. 106). Dongting Lake, a major flood-retention area in the middle reaches of the Yangtze, has lost 60% of its area to agriculture since 1825, whereas the Jianhan Plain, opposite Dongting Lake, has lost 80% of its wetlands to farmland since 1840. Wetland reclamation was a key strategy for grain production in 1950s, but this strategy was abandoned in the 1970s. Despite this, small-scale illegal reclamation occurs from time to time (Guangchun Lei, pers. com.).

The Chinese government has addressed these land management problems by a combination of ecosystem and structural measures. To reduce erosion, existing forests have been protected by a ban on logging and trees have been replanted, particularly on steep agricultural lands. A 10-year sand control program (2001–10) aims to convert 900 000 ha of farmland back into forest and grassland, and to reafforest 6 million ha of wasteland (Wang 2004, p. 165; (Onishi et al. 2005, p. 3; Pittock & Xu 2011; Zhang et al. 2006, p. 255). As well as having the effect of preventing erosion, silt is removed by dredging river beds and channel capacity is enlarged to increase the volume of water rivers can hold (Onishi et al. 2005, p. 3; Wang 2005).

While strengthening of key levees is an important measure for flood control, improved land management has become a key measure to mitigate floods. Since the 1998 floods, there has been increased regulation of polders and retarding basins has increased. Inappropriate (often illegal) dykes have been removed and people relocated to safer areas (Onishi et al. 2005, p. 3).

As well as removal of polders to return land to the river system, another strategy that has been used in a number of Yangtze lakes demonstration projects is the reopening of sluice gates to reconnect floodplain wetlands to the river (reminiscent of the Dutch Deltacommissie's 'closable open' sluice strategy to restore estuaries). This is a flexible approach enabling sluices to be closed for flood protection once flood storage capacity within the levees has been reached. The benefits of opening sluices have included improved water quality and the assisted the recovery of fish stocks and biodiversity (Yu et al. 2009; Pittock & Xu 2011).

Relocation

Relocation of people out of flood-prone areas is a measure that has been used in other countries, including Australia, but rarely with the speed and on the enormous scale with which it has occurred in China. Between 1998 and 1999, 337 000 people had already been relocated (Onishi et al. 2005, p. 5); in total, 2.4 million people have been relocated from the floodplains to higher ground since the 1998 floods (Pittock & Xu 2011, pp. 5–6).

Two alternative methods were used: 'single retreat', where residents were relocated but could still use agricultural lands in polders; and 'double retreat', where both residents and agricultural lands were relocated (Onishi et al. 2005, pp. 3–4).

The removal of polders in lakes and flood channels, and the relocation of communities that lived there, have been successful in reversing recent inappropriate land reclamation. According to Onishi, such measures resulted in 2900 km^2 of land being returned to lakes and rivers between 1998 and 2003, increasing flood storage capacity by 13 billion m^3 (Onishi et al. 2005, p. 4).

There is a compensation scheme; however, according to Onishi (after Cheng), the scheme is not fully established and has not been satisfactory, as successful relocation depends on the development of social infrastructure as well as compensation.

An example where social and economic factors were integrated is given in the Working with People and Governments section below.

Legislation, policies and planning

Land management and floodplain-restoration measures have been enabled by policy and legislative changes at central government level. Relevant laws include the Water Law (1988, revised 2002), the Law of Soil and Water Conservation (1991) and the Flood Control Law (1997). The provisions of these laws are outlined by Lang (2002) and Zhang (2004). They govern aspects such as cultivation practices (e.g. terracing, sediment traps, not cultivating steep slopes, afforestation, financial incentives), water quality, reversal of land reclamation, land zoning to include areas reserved for flood control where development is not permitted, impact assessment of development proposed for flood prone areas, integrated water resource management and the specification of responsibilities of government and citizens in flood control. While these national laws are sound, their implementation has often been inadequate due to conflicting and overlapping mandates, limited cooperation between different government agencies and poor enforcement (CCICED 2010, pp. 231–3).

The Flood Control Law came into force on 1 January 1998, just prior to the floods, but penalties were insufficient to prevent illegal activities (Lang 2002; Onishi et al. 2005). Following the 1998 floods, central government enforcement of environmental regulations relating to flood mitigation became much stronger. Supporting the Flood Control Law, the 32 Character Policy was introduced to be implemented over a 30-year period. The government has not only increased staff to monitor implementation and violations, but has also provided subsidies for land management transitions (Lang 2002, pp. 118–19). The subsidies are a form of Payment for Ecological Services (PES) scheme. There have been concerns that payments to those managing natural ecosystems are lower than those for lands being restored, and the limited timeframe for payments means that improved management over the longer term may not be sustained (Pittock & Xu 2011, p. 10). Nevertheless, initial indications are that implementation of flood policies are successful in increasing vegetation cover and restoring the active floodplain.

Planning for flood protection is based on population size and area of farmland. The National Flood Protection Standard Guideline gives a protection standard varying from a 1 in 10 or 20 year event for a population of 0.2 million or less (0.3 million ha or less) to a protection standard of a 1 in 50 or 100 year event for a population of 1.5 million or more (30 million ha or more) (Wang 2005). These standards are considerably lower than Australia's standard for residential housing of 1:100 years, probably reflecting the larger population pressures in China and the difficulty of keeping all out of harm's way.

Working with people and governments

Traditionally a country that takes a central, top-down approach to implementation, China has recently devolved some of this authority to local levels in the interests of economic development. Decentralisation has made it hard to enforce national environmental protection laws such as the logging ban and reafforestation of hillsides to mitigate floods. According to Lang, national laws that reduce employment or revenue are ignored or evaded at the provincial or county level if not strongly enforced (Lang 2002). Thus working with local interests helps to ensure cooperation.

Complementing its legislative measures, the Chinese government adopted an integrated water resources management (IWRM) strategy (CCICED 2004; Te Boekhorsts et al. 2010). This cross-sector approach takes account of the economic and social needs of local people.

The IWRM approach was used in two innovative programs to improve management of Yangtze lakes. Led by WWF, these programs achieved wide support from different levels and sectors of Chinese government, with donors including HSBC and local people. Pilot sites were established at Dongting Lake (one of the two lakes naturally connected with the Yangtze). Demonstration sites that restored seasonal linkages with the river were also established at a number of lakes that had been cut off from the Yangtze by dams and dykes (Yu et al. 2009; Pittock & Yu 2011).

The programs worked with local communities and governments to ensure that people benefited from the changes in floodplain management. Transition subsidies (for example, the Grain for Green scheme) from central government allowed immediate benefits for farmers, enabling them to discontinue harmful practices. Alternative livelihoods were developed that resulted in higher incomes with a more diverse base. In some cases, annual income increased by over 100%. Besides reduced flood risk, benefits included reduced exposure to shistosomasis, increased wild fish catch, improved water quality, health, services, housing and clean energy from biogas. The ecosystem also benefited, with greater numbers and variety of aquatic flora and fauna, including endangered species (Yu et al. 2009; Te Boekhorst et al. 2010; Pittock & Xu 2011).

Local and provincial governments have recognised the benefits to local communities, and the programs reportedly have inspired widespread wetland restoration and development of new wetland policies and regulations. The success of the programs is attributed to many factors, among them effective outreach and communication, the ability to adapt to the needs of stakeholders, the use of demonstration sites and effective linkage into government policies (Yu et al. 2009, p. 246).

6.1.3 Assessment of the applicability to Australia of Chinese approaches

China's recent strategies for flood mitigation are remarkable for their emphasis on environmental protection measures. These are 'no regrets' measures that improve the resilience of the entire basin system to withstand floods. The strategy for flood control in China indeed seems to be changing from 'keeping the flood away' to 'giving the flood way' (Yin & Li 2001, p. 108).

The Chinese take a whole-systems approach, quite different from Australia's more insular assessment of flood risk that doesn't usually go beyond the individual town or community level. Australian reviews, with the exception of the ENRC Inquiry, did not cover the role of vegetation or land management of upper catchments to mitigate floods for downstream towns. The ability of the floodplains to mitigate floods by storing them in natural detention basins, such as wetlands, was also omitted. Yet many of Australia's wetlands are cut off from rivers by levees, just as they are in China. These are both aspects that were identified by some Australian interview participants as requiring more attention.

There is great potential for Australia to explore a more integrated basin approach to flood control, including the consideration of vegetation and wetland restoration. The importance of working with people and ensuring that those affected by changes benefit is again reinforced by the Chinese example. Payment for Ecological Services to compensate land owners for employing compatible land management practices to mitigate flood is worth exploring.

Quick relocation on the scale that China has undertaken is less likely in countries without such a centralised government. By way of contrast with China, the compulsory demolishing and relocation of residential houses at Lent near Nijemegen in the Netherlands took at least 10 years to achieve (Nijssen 2011).

In Australia, adequate development controls that only allow flood-compatible development in at-risk areas tend to be a higher and more cost-effective initial priority than relocation. Relocation is generally (though not always) achieved through voluntary programs – for example, in areas susceptible to frequent flooding or in places that suffered substantial deaths, as at Grantham. To achieve relocation, cost-effective methods to relocate communities or individuals most at risk need to be identified, particularly in the window of opportunity when homes are significantly damaged or destroyed by flood.

6.2 The Netherlands

6.2.1 The resources selected

The primary references for the Netherlands were selected by the research team on the basis of their influence and/or innovation.

A key resource used was *Working Together with Water: A Living Land Builds for Its Future – Findings of the Deltacommissie* (Deltacommissie [Delta Committee] 2008)

The first Deltacomissie was formed following disastrous floods in 1953. That committee introduced risk-based approaches to flood protection and focused on engineering works to address threats. The report of the Deltacomissie2008 is the second major nationwide review of Netherlands flood defences. The second Deltacomissie was appointed not in response to a past flood event, but specifically to address future flood threats to coastal regions due to climate change.

The *terms of reference* of this review are expressed as a broad mandate:

> The committee's task is to advise the Secretary of State on:
>
> a. expected sea level rise, the interaction between that rise and the discharge in the major rivers in the Netherlands and such other developments, climatological and societal, until 2100–2200 as are important for the coast of the Netherlands;
>
> b. the consequences of such developments for the Dutch coast;
>
> c. possible strategies for an integral approach leading to sustainable development of the Dutch coast, based on a) and b) and
>
> d. to indicate the additional value to society of such strategies, in addition to the safety of the hinterland, in both the short and long term. (Deltacomissie 2008)

The terms of reference are expanded upon in a two-page explanatory note that emphasises the driving threat of climate change. It directs the Committee to identify future opportunities as well as threats; to consider temporal and spatial effects of options on the environment; to consider interactions between coast and rivers; and to take an intersectorial approach. There is an emphasis on innovative measures: 'creativity, imagination, and the ability to think outside existing contexts' (pp. 101–4).

The terms of reference are thus very broad and open-ended, leading the Deltacommissie to describe not only its mandate but also how the Committee interpreted it. The Committee described its task as 'how the Netherlands can be made climate proof over the very long term: safe against flooding, while still remaining an attractive place to live, to reside and work, for recreation and investment'. This articulates the mandate in terms of core societal values.

The two key issues identified by the Deltacomissie were water safety (in terms of both flood protection and securing fresh water supplies) and sustainability. The focus of the

latter was to identify flexible and cost-effective measures that give additional value to society, and that can be implemented gradually. The sustainability criterion also meant working with rather than against ecological processes and climate change (p. 9).

The Deltacommissie team comprised 10 members (including the secretary, also a water safety expert). The Committee was chaired by Professor CP Veerman, a specialist in sustainable rural development. Also on the committee were experts in the fields of climate science, hydrology, coastal engineering, economy, agriculture, local government, and spatial planning and urban development.

In addition to the Deltacommissie review, the following references and processes were examined:

- *A Different Approach to Water, Water Management Policy in the 21st Century* (Dutch Government 2000) – referred to in this report as the '2000 Water Policy'
- *Spatial Planning Key Decision Room for the River* (Dutch Government 2006) and the complementary Meuse Works program
- *Complex and Dynamic Implementation Processes: The Renaturalization of the Dutch Regge River* (De Boer & Bressers 2011) – referred to in this report as the 'Regge Report'.

These reports discuss some significant flood programs and policy approaches being implemented in the Netherlands that were initiated prior to the Deltacommissie 2008 Review, largely in response to a series of floods in the 1990s. They are complementary in that they focus on riverine flooding rather than coastal sea level threats. Two of these, the Room for the River and the Meuse Works programs, were assigned high priority for implementation by the Deltacommissie 2008 review. The third is a river restoration project on the Regge River that was initiated in 1998 and is due to be completed in 2018. The implementation of the project was recently the subject of a detailed study.

6.2.2 Similarities to Australian reviews

While there are many flood-related issues in common with Australia, generally there is little similarity in the approaches taken to address them. Some overlap occurs in measures such as amendment of administrative, institutional, legislative and management arrangements as well as adequate resourcing. Response measures such as warning systems and evacuation are important, but tend to be given less emphasis than more preventative measures. Spatial planning is an area that receives much attention and community participation is also seen as extremely important (though primarily in prevention/mitigation).

Similar to Australian reviews, the Deltacommissie (p. 77) and the 2000 Water Policy (p. 53) recognise the need for *defined roles, responsibilities and authority*. The Deltacommissie proposes legislative and administrative arrangements to achieve its recommendations, including a Delta Act, a Delta Programme, and national and regional bodies to ensure implementation. Current audit standards and methodology are found wanting in dyke maintenance programs and revised processes proposed (pp. 47–9). The report recommends a dedicated funding source isolated from normal budgetary processes in the form of a Delta Fund to ensure funding is not a constraint, using gas revenues and government bonds (pp. 77–84). Legislation to quarantine funds ensures partisan politics do not compromise flood security.

The Regge River restoration project report highlights the vulnerability of complex multi-sectorial projects to changes in national policies or regional administrative arrangements. Restrictions on organisational expenditure have recently been introduced, meaning that activities can only be funded if they have direct relevance to

their sector. This has resulted in a more *siloed approach* that is not compatible with integrated and multi-functional land-use projects (pp. 12, 196–7, 201). This is reminiscent of issues with Victoria's disaster management framework, where a siloed approach was not appropriate for the cross-sectorial nature of the task.

The *pressure for space* has resulted in competition for Dutch land between different sectors for residential, agricultural, industrial and infrastructure uses. The amount of land available for water and nature (excluding forest and woodland) decreased markedly between 1950 and 1990, by 15% and 44% respectively, while agricultural land area decreased by approximately 6% (De Boer & Bressers 2011, p. 17).

Even though Australia has fewer population pressures than the Netherlands, Australian urban centres experience significant space pressures, resulting in concerns that floodplain land not be 'sterilised', or unnecessarily made unavailable for use (NSW Government 2005). In the Netherlands, there is a similar concern not to prohibit development on flood-prone land. The Deltacommissie, while discouraging development on such land, recognises space scarcity and takes the view that, providing river discharge capacity is not impeded, and providing the ability to increase levels of water storages is retained, floodplain development could take place using innovative building design, amendment of building regulations and structural measures (pp. 49, 52, 90). Possible building design measures include houses on floating platforms, houses on stilts, use of waterproof materials (if flooding is shallow but frequent) and the use of artificial mounds in areas with little flow. These artificial dwelling mounds, or 'terps', have been used in the Netherlands as defence against flooding since the Middle Ages. This measure is being reintroduced in some areas that are being depoldered as part of the 'Room for the River' program (reversing land reclamation measures). Relocating businesses and homes to mounds enables people to continue to live in these areas (Dutch Government n.d.a).

Dutch documents reveal conflict between municipalities that are responsible for development planning and Water Boards, which have an interest in leaving areas at risk of inundation undeveloped. The Dutch government is concerned that too much land has been reclaimed from river systems that now have insufficient space, resulting in higher flood risk. Its 2000 Water Policy requires all new spatial planning to be subject to a water test:

> The 'water test' applies to all manner of spatial planning decisions, including amendments to zoning plans, regional plans, new plans for infrastructure, residential construction, business parks and redevelopment plans in urban and rural areas. The 'water test' allows the consequences for safety and water-related problems to be assessed in relation to the ramifications on water quality and dropping water-tables. (Dutch Government 2000)

Water and its natural movements are now 'a key determining factor in spatial planning' (De Boer & Bressers 2011, p. 25; Dutch Government 2000, p. 43).

This is reminiscent of the situation in Victoria, where councils need to refer development approvals in flood prone areas to catchment management authorities – although in the case of Victoria, the government has chosen the opposite approach and is removing assessment powers from catchment authorities (Comrie 2011; Ryan 2012).

While the Dutch government does not prohibit development on flood-prone land (Deltacommissie, pp. 49–52, 90), it is much less willing to subsidise the consequences than the Australian government has been. The Dutch government sees its role in managing floodplain development (outside dyked areas) as '[to] inform, advise, alarm

and (if necessary) evacuate and [to] impose building requirements'. The costs of construction and maintenance of protective measures, as well as the costs of flood damage and reconstruction, are to be borne by residents and users who benefit, and not passed on to different administrative levels or society in general (Deltacommissie, pp. 49–52). However, the government is subject to compensation claims resulting from flood damage to areas within dykes where safety levels apply (Dutch Government 2000, p. 63).

The issue of *insurance* arises in some documents, with a government task force set up to investigate 'the (im)possibility of insurance coverage for weather sensitive sectors'. The taskforce aim was to make flood damage insurable, though it is not clear if affordability was also a concern (Dutch Government 2000, p. 23). Insurance against flood continues to be unavailable in the Netherlands (Petherick 2011). The Deltacommissie gives a brief but pertinent commentary relevant to insurance and community resilience in its Appendix 4:

> Looking at the organisation of flood protection, one can discern an Anglo-Saxon style, based on a great deal of individual responsibility and the operation of the market, and a Continental style with the government taking responsibility. Lessons from the USA and the UK teach us that leaving responsibility to individuals does not always mean that they accept it … Flood protection often remains confined to local 'postage stamps' based on local cost-benefit considerations and so do not always form a consistent whole … Damage control and disaster management (and insurance) are better organised in countries with poorer levels of protection (and more frequent flooding). (Deltacommissie 2008)

While this suggests that community resilience is not given as much emphasis in the Netherlands as it is in Australia, *community involvement* is significant in the Dutch approach to land-use changes. It is also worth noting that, in the Netherlands, local communities have significantly more autonomy and power than they do in Australia, which also gives them local responsibility.

The need for community involvement is highlighted in the Deltacommissie Report (pp. 45, 79). The effectiveness of this strategy is demonstrated in the Regge River renaturalisation project. This is a large and complex project aiming to restore the entire length of the river for the dual aims of water storage (buffering capacity in times of flood) and nature conservation. The project was broken up into numerous sub-projects to make it more manageable, working with various communities and municipalities along the length of the river. The project required land to be acquired along the river and/or for its designated use to be changed. A decision was made for the project to employ *voluntary* measures. This was seen as extremely important, as projects in neighbouring areas that used compulsory means to change land use took 20-30 years to complete due to opposition (p. 106). The community consultation strategies were extremely successful in preventing conflict and lengthy litigation processes (pp. 106–7, 126–30, 148, 154, 177–8, 184, 201).

Community involvement strategies are currently being employed on a much larger scale to implement the Wealthy Waal Programme. This programme aims to provide more room for the Waal River to accommodate higher river discharges, while at the same time identifying opportunities for joint benefits for achieving other objectives, such as shipping, economic activity, farming, nature protection, tourism and recreation (De Hartog 2012).

Community involvement was also used successfully in the Room for the River program at Nijmegen to reduce conflict following a controversial decision to relocate a dyke and demolish 50 houses (Nijssen 2011, p. 4); Dutch Government n.d.a, p. 7). This location

was particularly vulnerable to flooding, as a narrow bend in the river formed a bottleneck, causing water to back up during a flood. Once a decision had been made by central government, the municipality affected was granted responsibility for developing a plan that would be acceptable to all parties (a similar strategy was successfully used at Diepenheim for the Regge project, pp. 106–7).

Raising community awareness of flood risk is an issue that receives attention, but more in the context of achieving political support for new water safety measures rather than community resilience (Dutch Government 2000, p. 21).

Evacuation as a measure to reduce the consequences of climate change is largely left untouched by the Deltacommissie Report, as it is focused on prevention rather than contingency. However, an early warning, crisis management, evacuation plans, routes and locations are listed in the mix of measures that should be used (pp. 41, 119). Other Dutch literature covers response mechanisms in more detail. Evacuation of people and cattle was on a massive scale in the 1995 floods, and 250 000 people and 100 000 cattle needed to be evacuated (Dutch Government n.d.b, p. 16). Thus, even if it is not the primary focus, it is a very significant strategy for the Dutch. As in Australia, municipal governments are responsible for developing evacuation plans (Dutch Government n.d.b, p. 48). The Dutch use tools such as the 'Standard Method for Calculating Flood Damage and Victims', which maps the number of victims and expected flood damage, to assist the assessment of evacuation needs. Other tools help plan evacuation routes. Work has also been carried out on evacuation decision-making, to determine when to evacuate – for example, Frieser's work on a probabilistic evacuation model rather than a deterministic approach (Frieser 2004). Determining suitable evacuation routes and trigger points has also been an issue in Australia (Opper 2000; Queensland Inquiry interim report, pp. 188–92; Queensland Inquiry final report, pp. 173–5). Response concerns such as these show little fundamental difference to those expressed in Australian reviews.

6.2.3 Different approaches

The approach taken by the Netherlands to flood review and flood management is remarkably different from the Australian approach. While the Australian reviews are very much focused on analysing a past flood event to improve the outcomes of future events (with similar characteristics), documents from the Netherlands are firmly focused on changes to future flood threats.

The review process

As seen above, the terms of reference of the Netherlands Deltacommissie are quite different from those of the Australian processes, allowing latitude for innovation and specifically asking for measures that can address accentuated flood risk due to climate change causes. They do not call for detailed analysis of a past event, which seems to result in less focus on finding out what went wrong with a specific event's preparation, response and recovery. It is more concerned with broader prevention and mitigation strategies. Interestingly, the Dutch terms of reference specifically call for investigation of opportunities. This is very important in shaping the receptiveness of people who are asked to adapt to climate change threats. If climate change is only seen as a looming threat of massive proportions, it becomes a monster from which people shy away. Transformed into positive opportunities to create more land or to improve its quality, safety and economic advantages, adaptation to climate change becomes much more digestible.

Although the Deltacommissie explains that its purpose is not so much to respond to a past event but to anticipated future events (Deltacommissie 2008, p. 7, this is not the entire story, as the Deltacommissie builds on previous work, such as the 2000 water

policy ‘A Different Approach to Water’ and river restoration programs. These were developed in response to a series of flood events in 1992–93, 1995 and 1998 that caused widespread evacuations and property damage (De Boer & Bressers 2011, p. 24). The floods could have been much worse than they were, and are described in some documents more in terms of a near miss as dykes were not breached (Dutch Government 2000, p. 11; Dutch Government n.d.a, p. 5; Dutch Government 2006, p. 7). While the Deltacommissie Report responds to anticipated threats, it was the floods of the 1990s that caused the Dutch to reassess their water policy and much of the thinking, and even the language of the Deltacommissie reflects the 2000 Water Policy. The flavour of the Dutch review is far-sighted, visionary, proactive and enabling. Differences are evident in the treatment of climate change, safety standards, the implementation timeframe, the emphasis on structural protection measures, ecological processes and quality of life. There is a heavy emphasis on multifunctional land use and optimisation of benefits for all stakeholders.

The Deltacommissie Report was well received, and made a substantial contribution to the awareness of the impacts of climate change for the Netherlands. All the main recommendations were accepted by the Dutch Cabinet, and it was also ‘warmly accepted by politics and in the media’ (Verduijin et al. 2012).

One of the most striking differences when comparing the review processes of Australia and the Netherlands relates to the size and detail of the reports. The Deltacommissie (134 pages including appendixes) produced 12 recommendations, whereas the final Victorian Review (234 pages) produced 93 recommendations, and the Queensland Inquiry, with both reports taken together, was 916 pages long and produced 352 recommendations. Yet it could be argued that the Dutch process is far more likely to make a durable impact on the way flooding is managed. The fact that some of the Committee members were professional writers in addition to their primary areas of expertise (one with experience in journalism and another as a novelist) may also have enabled them to convey their message in a style that was engaging and influential (Verduijink et al. 2012; Deltacommissie n.d.).

Climate change and other future threats

Climate change is the motivating force behind the Netherlands’ Deltacommissie 2008 (see terms of reference above). It is also stated as being a primary consideration in the 2000 Water Policy, the Room for the River and river renaturalisation projects such as the Regge River. The Deltacommissie report analyses and quantifies the threat of climate change over a long timeframe (pp. 21–31), finding inadequacies in stream discharge capacity, reliability of structural defences, water quality and water security, ecological and social consequences, and economic consequences in terms of direct damages and impacts on tourism, navigation, agriculture and loss of land to the sea.

Other future threats, such as population increase and the location of economic growth centres, are also identified in the Deltacommissie report, contributing to the identification of appropriate adaptation measures and priorities (p. 32). Future risk determinants such as demographics are largely ignored by Australian reviews.

Quantifying the threat (and deliberately using the worst-case scenario) enables appropriate measures to be identified that can be implemented incrementally over a 200-year timespan, enabling flexibility to be retained and cost-sharing by current and future generations (pp. 27, 41, 82). The review does not provide an exact blueprint plan of implementation, but it delivers a vision and broad strategies to achieve objectives. Recommendations are provided for three time horizons: more concrete measures for immediate implementation by 2050; a clear vision for the period 2050–2100 and long term considerations beyond 2100 (p. 45). They are designed so that current adaptation

measures do not compromise future adaptation options (for example, housing development should not be permitted in areas identified as potential water storage areas in case it becomes necessary to increase dam heights: Deltacommissie pp. 52, 95). This ensures that flexibility to deal with future risks and uncertainty is retained. Clear vision with flexible temporal and local implementation is also used in the Regge revegetation project (Regge Report, p. 37) and 'Room for the River' (Dutch Government 2006, pp. 10, 13, 16; Nijssen 2011).

The Deltacommissie identifies not only how to protect the Netherlands from the effects of climate change, but also how to create opportunities from it. Besides flood protection, opportunities are identified in water quality and availability (pp. 53, 57–9), agriculture (p. 27), recreation (pp. 39, 53, 71), scenic landscapes (pp. 39, 71) and biodiversity (pp. 39, 52), creation of space for housing and innovative building design (pp. 48, 52–3), and economic benefits including shipping (p. 71), energy generation (p. 39, 68, 73) and aquaculture (p. 73).

The Dutch head-on, opportunistic attitude to climate change risks contrasts with the Australian flood reviews that (both in terms of reference and report content) avoid climate change in a way slightly reminiscent of Basil Fawlty's injunction, 'don't mention the war'. When it is mentioned in Australian reviews, it is only in terms of a negative threat that increases municipal liability, reduces land value and introduces scarcely manageable uncertainty.

Drain or retain

In the Netherlands, rivers are highly modified. Since the mid-1800s, the Regge River has been canalised, re-engineered and regulated to ensure faster drainage for agriculture. Farmers in Victoria are currently calling for similar measures, to clear vegetation and increase channelisation in order to drain water away faster (Parliament of Victoria 2012, pp. 114–18). It is therefore worth considering the reasons why the Netherlands is going to great trouble and expense to reverse this policy.

In the Regge River example, river modification has compromised many other river functions, including groundwater recharge and space for natural habitat. Water-storage capacity has been reduced by cutting out meanders and confining the river between narrow banks. This has left less space for floods to spill into, causing higher flood peaks. River modification has also compromised cultural heritage in some areas, with dry moats causing damage to castle foundations (pp. 9, 43, 111, 145).

More recent Dutch water policy is holistic, in that it identifies adaptation measures that simultaneously address climate related issues of drought, flood and water quality. The Dutch strategy is to retain precipitation for as long as possible in the catchment where it falls, then (temporarily) store floodwaters, only draining them when capacity of 'retain and store' have been reached. This enables the replenishment of groundwater that has been depleted during drought and at the same time helps form a barrier to prevent salt water intrusion. It also ensures that flood problems are not simply transferred to those downstream (Dutch Government 2000, pp. 32–3). The method used to achieve this is to allocate more space to water. Measures include increasing the size of active floodplains, lowering them (including through clay extraction for brick production) and restoring meanders and wetlands, and creating water-retention areas (Dutch Government 2000, pp. 32–6). Another benefit of delaying the release of floodwaters would be to increase warning times for downstream communities.

The allocation of land for rivers is seen as a valid land use in itself, providing services such as flood control and water quality. The reservation of land for water services is not seen as under-using the land. Rather, the scarcity of land causes the Dutch to take a multifunctional approach, identifying compatible land use on land allocated to water, with

agriculture, recreation, nature and flood management seen as good partners (see Deltacommissie, p. 39; 2000 Water Policy, p. 31). This is a consistent feature of Dutch projects. In the Regge River example, land allocated to water management purposes is used to improve scenic value and attractiveness of the area for both residents and tourists, also boosting property values (p. 114). There are also co-benefits in nature conservation, cultural uses (e.g. art, festivals), preservation of heritage (e.g. the return of historic river boats), navigation, compatible agriculture (e.g. non-intensive grazing) and infrastructure such as bridges and bike paths (e.g. see pp. 121, 132, 171, 176–7). In some areas, this multifunctional approach has also stimulated rural economies (e.g. pp. 139–48). Similar multifunctional objectives have been achieved in the Room for the River Programme (Nijssen 2011, pp. 4–6).

Dykes and other structural measures

The case of the Netherlands is instructive, as it could be described as an extreme example of the use of levees, upon which so many Australian country towns depend.

To protect themselves from floods, the Dutch began constructing terps (artificial mounds to build upon) from about the ninth century. Dykes were built from the thirteenth century, both for flood protection and to reclaim land for agriculture. The process of land reclamation was facilitated between 1250 and 1600 by the introduction of windmills, enabling water to be pumped out of dyked areas. This also caused land to sink deeper as the soil dried out and the peat decomposed. As one author put it, 'the Dutch pumped themselves under the sea level' (Hallie & Jorissen 1997). Some 50% of the Netherlands is currently below sea level.

Over the centuries, the Dutch developed highly sophisticated water-management systems to protect themselves from flooding, not only in the form of dykes, sluices and drainage canals, but in management and funding mechanisms to maintain them. Described as the oldest democratic institutions in the Netherlands, Dutch Water Boards were formed from the thirteenth century to regulate and maintain flood defences (and, more recently, to ensure water quality). Water Boards have the right to levy taxes from people within their water board areas, giving them a high degree of independence from national politics and budgets (Lazaroms & Poos 2004). Dykes have been raised higher and higher, to retain ever greater volumes of water and development behind them has increased, leading to ever-increasing consequences should defences fail. While Dutch dykes may be in a different category to Australian levees, Smith's paradox[9] still applies (Smith 1998).

In a nation that has a history of tight structural control over water, it is interesting that the current approach centres on a recognition that dykes cannot be raised continually higher or the consequences of failure will mount (2000 Water Policy, pp. 27, 31). Moreover, the higher dykes rise, the higher the pumping costs to remove water from the areas they protect (Deltacommissie, pp. 67–9). Dyke reinforcement is a primary measure supported by the Deltacommissie (pp. 41, 47–9, 67). However, other measures are also used. The approach used in the 'Room for the River' program is to restore floodplains and allow floodwaters to spread over a wider area to reduce water depth. The activities to achieve this are still largely structural as it is not possible to simply remove dykes when 50% of the land is below sea level; dykes are relocated inland, secondary water channels excavated and river beds, groynes and floodplains lowered. Forming separate compartments within dyked areas creates a secondary line of defence. For some polders (areas enclosed by dykes), partial lowering of dykes will enable water to flow

[9] Smith's 'levee paradox' describes the commonly observed phenomenon that when you protect areas from flooding by levees, it has the perverse effect of encouraging development behind them, increasing the potential for damage should levees be overtopped or fail (Smith 2004, pp. 232–4).

through polders when water levels are high. As a consequence of having more space to spread, flood peaks will be reduced and safety will increase (Netherlands Government 2000).

The Deltacommissie recommends a number of other structural measures. 'Closeable open' storm surge barriers are a flexible solution proposed to help to control water levels in estuaries. These can be closed temporarily when high river discharge coincides with storm surge (in which case water retention areas would be used until floodwaters could safely be released). They could also be permanently closed if sea levels rise too high. In the meantime, having gates that are able to be open for most of the time enables natural tidal dynamics and salt/freshwater gradient that is good for habitat value, navigation and tidal energy generation. As barriers will act as dykes, they could also open up new areas for potential waterfront development (Deltacommissie, pp. 63–6).

Beach nourishment forms a large part of the Deltacommissie's coastal strategy. Sand is dredged from the continental shelf and spread on eroding flats or along dykes. This measure is currently used in Dutch coastal management. The report recommends massively increasing these efforts. Beach nourishment would be on such a large scale that beaches will not only keep pace with climate change sea level rise, but will actually widen the coast by about 1 km in a century. Benefits anticipated include increased safety for existing coastal resorts, more space for nature (coastal habitats being quite degraded over the last 150 years; see also Regge Report, p. 17), recreation and more land for development. However, the Committee recognises that there are energy efficiency, economic and ecological implications. Greater research into these aspects was recommended by the Committee. The possibility of creating offshore islands or reefs to protect the coast was considered, but beach nourishment was identified as the best option for reasons of cost-efficiency and because islands would have the potential to increase coastal degradation issues (Deltacommissie, pp. 52–5).

Reserving land for water

The Deltacommissie report stresses the importance of reserving land to restore the water storage capacity of the floodplain. It primarily recommends land purchase to achieve this, including reserving land under a permanent preference right, to allow purchase at such a time as the owner is prepared to sell it, and also to purchase strategic land positions when the opportunity arises (p. 61). Unlike the Regge River project, where voluntary approaches were used, the Deltacommissie stresses that 'climate-proof' spatial planning in respect of building in unfavourable locations and early involvement of water managers 'must not be voluntary' (p. 96), though compensation is stipulated. The Dutch are not averse to compulsory measures with respect to water management if they are seen to be in the national interest (Regge Report, pp. 31–2; Nijssen 2011, p. 4). With 50% of the land area below sea level, they cannot afford to be.

The Regge River project used voluntary participation to reserve land. A particularly successful strategy was to purchase land in advance and then use it to exchange with land that was needed to realise the project. The advantage of this was that it enabled farmers to continue farming (overcoming resistance), and it prevented property owners from opportunistically elevating the price of their land (p. 117). Patience was particularly important in acquiring land, highlighting the importance of a durable, long-term strategy (p. 191).

Changing the designation of land to reflect its revised use was sometimes delayed as 'municipalities had quite often not made or updated *local land use plans* for their non-built-up-areas' (Regge Report, p. 30). However, the Regge project provided an opportunity to update land-use plans so they would be flexible and facilitate changes in land use designation from agriculture to 'new nature' by including an 'acceptable changes' layer in their land use plans (pp. 163, 168). The plans (that identify acceptable

changes) are subject to public scrutiny during initial drafting; however, once approved, 'acceptable changes' only need to go through the city council. Changes in land designation from agriculture to nature reduce property value by about one-third, but participation is voluntary and compensation is paid. In the case of the Regge project, calculations were done on the basis of the difference in land value over a 30-year period. Separate amounts were also provided for allowing the land to be used as a water-retention area in times of flood and for annual maintenance activities, as part of a Payment for Ecological Services scheme (pp. 160–1, 175).

Land ownership requires ongoing land maintenance, and Dutch Water Boards sometimes transfer this role to other public bodies responsible for nature conservation. While the Regge River project purchased land, it also recognises that public ownership of the land is not necessary to achieve project objectives – the same objectives can be achieved by measures such as rezoning and land-use covenants (p. 175).

Australia does have examples of land acquisition to reduce vulnerability to flooding, but this has not been a standard practice. In Victoria's Lower Loddon catchment, properties most at risk of flooding have been purchased and resold with a covenant to restrict agricultural practices to more resilient dryland farming, and allowing properties to flood. In Grantham, Queensland, the whole community was relocated to higher ground after the floods, with plans to use the old site of Grantham for more compatible purposes. However, these are isolated examples that were initiated partly to help flood-damaged communities to recover, rather than being part of a durable nationwide (or statewide) flood prevention policy.

Water safety

Australia tends to have a low tolerance to accidental death, including flood deaths. There is no political guidance on socially acceptable levels in the National Disaster Resilience Strategy, and no political debate. The Queensland Inquiry did not examine what the acceptable number of deaths should be for such an event. As an inquiry into a recent event where some communities lost many lives, this would have been insensitive. The Victorian Review (where no deaths occurred) suggests that emergency management needs to 'deliver an acceptable measure of safety and security to the community' without defining what this is.

The Dutch are more pragmatic in recognising that it is not possible to prevent all disaster-related deaths. They have conducted studies to assess the amount of money that goes into preventing traffic fatalities as a basis of determining the economically optimal safety level (Dutch Government n.d.b, p. 52). They have also compared safety standards for other types of incidents, commonly set at a probability of one in a million per year. The Deltacommissie proposes that this level should be applied as the minimum standard for each individual in every locality (within dyked areas). The Deltacommissie is also concerned that other water safety elements need to be incorporated into the minimum safety standard for each area, including societal or group risk (the probability of large numbers of simultaneous casualties), and flood damage, including both direct and indirect costs. The broad interpretation of 'water safety' is stressed, including cultural and environmental assets, societal disruption and reputational risk, among others (Deltacommissie, pp. 41–3, 96, 118–23).

The Dutch approach to water safety is highly engineered. Australia starts with the physical landform and, via flood studies, determines flood risk and (ideally) zones accordingly (if flood studies have been carried out and if they are incorporated in municipal plans). The Dutch, on the other hand, start from the premise that people are entitled to a safety factor and then ensure that appropriate measures are in place to give them this, primarily in the form of structural measures such as dykes, but also other

measures such as spatial planning, early warning, response and contingency planning (p. 41). Their land planning is not governed by whether or not land is within the 1 in 100 year flood line. Dutch measures manipulate that line, so that protection should be sufficient to defeat a 1 in 10 000 year event in North Holland (in view of the value of the interests that need to be protected). In other coastal regions, it is 1 in 4000 year and for riparian areas the standard is 1 in a 1250 year event (due to reduced damage resulting from fresh as opposed to seawater)(Deltacommissie, p. 40). The reason for this difference could be attributed to Australia's low population density outside cities. This means that flood defences in most rural areas target 'high-value' assets like towns through isolated and ad hoc levee systems. The Netherlands is densely populated over its entire area, requiring more systemic management of floods along rivers.

The Deltacommissie reports that, according to a recent EU Directive, every river basin needs to have a flood-risk management plan (p. 62). This is interesting in that the flood plans are to be based on geographic catchment boundaries, rather than artificial administrative boundaries, as is often the case in Australia.

Conclusion of 'differences'

For the Dutch, the 1990s flood events revealed that business as usual in the form of fighting against floods with ever taller dykes and other structural measures would be insufficient to deal with new emerging threats; analysing recent floods and reactively patching up holes in existing frameworks and organisations would not make the Netherlands safe for the longer term. This resulted in a fundamental reassessment of existing water policy and centuries-old water management systems. Central to their revised approach is floodplain restoration, with its multiple benefits – a measure that received little, if any, attention in Australian reviews (although Victoria's flood mitigation review, yet to be released, may cover this to some degree).

6.2.4 Assessment of the applicability of the Netherlands approaches to Australia

Today, 50% of the Netherlands is below sea level, its lowest point being 6.74m below sea level at Nieuwerkerk, and 65% of the country's wealth is below sea level. This makes the Netherlands extremely vulnerable, to the extent that flood risk is a supreme issue for national security and large funds are available for investment in flood measures. The national scale of the threat also explains why the Netherlands uses a much more conservative flood likelihood standard than other countries, to compensate for the extreme consequences should a flood happen (Deltacommissie 2008; Dutch Government n.d.a).

In Australia, a significant amount Australian wealth is located in coastal areas and is threatened by flooding as a result of sea level rise (Australian Government 2009). Inland flooding is also likely to become more severe. However, flooding is unlikely to be a national security issue as it is in the Netherlands. In Australia – the country with the most natural variability of weather patterns in the world – some find the El Niño–La Niña cycle of greater overall significance than perceived gradual changes in climate change. Funds to implement structural measures on the scale of the Netherlands are unlikely to be made available, and planning for rare events on the scale of 1 in 10 000 years (for the Netherlands north coast) or 1 in 1250 years (for most riparian areas) are unlikely to become the standards adopted for residential development in Australia.

Some of the measures used by the Dutch are inappropriate for Australia. It is difficult to see how beach nourishment would be acceptable as a measure to counteract rising sea levels and storm surge, given the damage it would do to coastal ecosystems. In Australia, use of more natural mangrove 'bioshields' may be a more appropriate measure. Use of dykes along riverbanks in flood-prone cities such as Brisbane is equally

unlikely to be popular, as well as expensive (this measure was considered in the Brisbane Review and discarded – see p. 62).

Despite this, the Netherlands has some valuable lessons for Australia to help it manage flood. There is potential for the 'retain–store–drain' and 'room for the river' approaches, ensuring more land is allowed to flood by removing or setting back floodplain levees to reduce their severity. Such measures may have added advantages, enabling replenishment of groundwater resources to counteract prolonged drought, the flipside of climate change. There are advantages in the co-benefit approach to land use where space is scarce, this providing optimal outcomes to stakeholders and enabling cost-sharing of projects by multiple sectors.

The importance of considering cultural heritage in relation to flooding is evident in the Regge River project and is also underlined in the Deltacommissie report (p. 37). Many of Australia's earliest European settlements were sited in the most vulnerable flood-prone confluences, and Aboriginal heritage (e.g. coastal shell middens) is also likely to be threatened by flooding related to sea level rise (Smith 1998; Pearson 2007). The resilience of cultural heritage was not an aspect covered in Australian flood reviews, but following the Dutch example, this is something that should be given greater consideration in Australian flood-management strategies.

The Dutch do not skirt politically difficult issues such as climate change and acceptable flood mortality. By putting figures on the table, they are able to open up debate on these issues to determine what needs to be done about them. The solutions they have come up with, like the use of dykes, or the adoption of a flood death probability of 1 in a million per year for each individual as a minimum standard, may not be the solutions Australia adopts. However, the political courage to face such issues represents leadership from which Australia could learn.

Australia's disaster review process could also merit examination. Australia's flood reviews were incredibly detailed and lengthy (some flood professionals confessed to not having had time to read them). A review's analysis of what can go wrong in a flood event is instructive, but the same issues come up each time there is another flood (Handmer, pers. com.). This raises the question of whether the current review approach is an effective one. The review process tends to retrospectively patch up holes revealed by past events. Many failures in the 2010–11 floods were the result of human error rather than inherently bad systems, and many successes were entirely due to the unusually skilful efforts of individuals in the absence of administrative processes. A new set of faces and circumstances during the next flood will reveal new and slightly different gaps in the system. This approach is not necessarily effective in preventing future disasters – certainly not for nationwide floods that might only happen every 10–30 years. The Deltacommissie, because it did not have to review any specific event, was free to focus on addressing flood risk in the long term. The firm vision and flexible implementation over a 200-year timeframe are remarkable. Moreover, the manner in which it has been framed and the accessibility of its writing style have resulted in a document that is influential and arguably more widely read than its Australian counterparts.

An examination of documents from the Netherlands reveals strong spatial planning mechanisms imposed from the national level (with flexible local implementation). Water management is clearly seen as an issue of national concern, as any under-estimation or inaction in addressing future flood risk could have severe consequences. Such a national approach is harder to achieve in a federal state like Australia. Under Australia's Constitution, state governments have primary responsibility for natural resources. The federal government's role is limited unless it is invited by state governments or chooses to legislate using its powers to regulate corporations or to fulfil national obligations under treaties, including those related to wetlands and climate change. However, according to

the Council of Australian Government's National Disaster Resilience Strategy, greater focus needs to be given to prevention, and not just response. The implementation of this strategy could provide an avenue to develop a more cohesive approach to development planning. The use of PES schemes and a variety of land-reservation methods that enable appropriate land use and multifunctional approaches could all be used to improve development outcomes and Australia's flood resilience.

6.3 United States

6.3.1 The resources selected

The primary references for the United States were selected by the research team and by collaborating researcher Professor Gerry Galloway of the University of Maryland. They were selected on the basis of their influence and/or innovation.

A large number of review processes have recently been conducted both by state and national organisations. These have been concerned primarily with the effectiveness of levees, dams, flood mapping, the adequacy of the 1 in 100 year flood insurance standard and the federal flood insurance scheme. Recent reviews include:

- Evaluation of the National Flood Insurance Program (2001–06), commissioned by the Federal Emergency management Agency (FEMA)
- Review and Evaluation of the National Dam Safety Program (2011), commissioned by FEMA
- *The National Levee Challenge: Levees and the FEMA Flood Map Modernization Initiative* (2006), a report by the Interagency Levee Policy Review Committee, commissioned by FEMA
- *A California Challenge: Flooding in the Central Valley*, *a Report from an Independent Review Panel to the Department of Water Resources, State of California* (2007)
- *Living with the Red: A Report to the Governments of Canada and the United States on Reducing Flood Impacts in the Red River Basin* (2000) by the International Joint Commission
- *Mapping the Zone: Improving Flood Map Accuracy* (2009), commissioned by FEMA
- *Mississippi River Commission 2011 Mississippi Rivers and Tributaries Flood Report*
- Performance Evaluation of the New Orleans and Southeast Louisiana Hurricane Protection System by Interagency Performance Evaluation Task Force (IPET), appointed by the United States Army Corps of Engineers (USACE) (2009)
- Review of the Regulation of the Missouri River Mainstem Reservoir System During the Flood of 2011 (appointed by USACE)
- *Recommendations for a National Levee Safety Program: A Report to Congress from the National Committee on Levee Safety* (2009), a report to Congress
- *Disaster Resilience: A National Imperative* (2012), a report by the National Academies sponsored by eight federal agencies, including USACE, FEMA and NOAA.

In addition, there has been significant activity from organisations such as the Association of State Floodplain Managers and the National Association of Flood and Stormwater Management Agencies, which has produced position papers and recommendations on levee policy.

6.3.2 Review processes

Review processes in the United States are not concise. The review of the NFIP was conducted over five years and resulted in 16 volumes by well over 50 authors from numerous organisations. A review of hurricane defences following Hurricane Katrina, organised by USACE, was produced in nine volumes over 3.5 years. These were subject to an independent peer review that produced a number of review reports. The reviewers made the point: 'The IPET draft final report of June 2008 contains roughly 7500 pages. A document of this size presents considerable editorial challenges in fully and clearly presenting its main findings and recommendations.' (Committee on New Orleans Regional Hurricane Protection Projects 2009, p. 20). While Australian flood reviews are lengthy, they seem modest compared with US examples.

Most US review processes are very careful to ensure a degree of separation from the commissioning agency to ensure independence. Memberships of review panels are frequently diverse, coming from universities, consulting agencies, non-profit associations, relevant industry sectors and government agencies. It is of interest that the numerous recent reviews appear to have reached similar conclusions about key issues such as levees and the adequacy of using the 1 in 100 year flood event as a tool for managing floods.

6.3.3 Approaches to flood management

The United States has had enormous influence on the management of floods globally. America pioneered the 1 in 100 year flood insurance standard as 'a measurement to balance avoiding inordinate flood losses with avoiding excessive regulation of floodplain development' (Wright 2000, p. 25). It was also the United States that produced legendary geographer Gilbert White, who set the course for non-structural approaches to flood control.

The term 'floodplain management' was first used by the Tennessee Valley Authority (TVA) as early as the 1950s, when it successfully applied White's ideas in the Tennessee River Basin, preventing significant damage costs. The TVA program included the creation and provision of free flood information (maps and studies) to 112 communities at risk, and the TVA worked with them to adjust land use via floodplain regulation. Partly due to the success of the TVA's efforts, non-structural flood control measures gained wider acceptance by US governments. The first nationwide US inventory of urban flood-prone areas was published in 1967. Subsequently, national standards for flood insurance studies (including the 1% flood standard) were finalised in 1972 (Wright 2000, pp. 17–21, 25). By contrast, Australia has only recently embarked on its first attempt at creating an inventory of flood studies at a national level, through Geoscience Australia's Australian Flood Studies Database, following a COAG decision in 2003 (Middelmann et al. 2005). Its *National Flood Risk Information Project* (announced November 2011) has only recently begun developing national guidelines for the collection, comparability and reporting of flood-risk information (Attorney-General's Department 2012c).

Flood management in America has been strongly influenced by the establishment of the National Flood Insurance Program (NFIP) in 1968. To a certain extent, this legitimised the federal government's involvement in development controls, which continues to be primarily a local government responsibility in the United States. Under the NFIP, the federal government provided subsidised flood insurance premiums to existing floodplain occupants in designated flood-prone areas (for property within the 100-year floodplain, as delineated on a flood insurance rate map). This was contingent on the use of regulations to control future development. Future occupants of floodplains were to pay the full cost of premiums based on flood-risk information provided by the program (Wright 2000, p. 34). Today, about 25% of policies continue to be subsidised. While

Australia has not taken this path, the recent Natural Disaster Insurance Review proposed federal government involvement in a subsidised flood insurance scheme (Trowbridge et al. 2011), and it is therefore worth exploring some of the pitfalls of the American scheme.

In the United States, the federal government is heavily involved in disaster assistance, with ever-increasing numbers of disaster declarations and amounts allocated to disaster recovery. This trend towards federal disaster relief has grown significantly in the United States since the start of the 1990s (Wright 2000, pp. 67–93). Given that recent Australian government commitments to flood disaster relief for Queensland alone totalled $5.6 billion (Gillard 2011), approaches to flood recovery merit further examination.

6.3.4 Climate change and other future flood risks

All American reviews and reports acknowledge climate change to some degree, and recognise it as a factor that increases future flood risk that needs to be planned for. The USACE report on Hurricane Katrina notes the recent increase in intensity and frequency of hurricanes and, when discussing hazard assessment, makes the point that 'traditional methods of extrapolating data are inadequate in that they assume the past is representative of the future' (USACE 2009). A recent report to Congress on climate change and water resource management prepared by four federal agencies recognised the necessity for changes to planning and analysis that would better accommodate non-stationarity (Brekke et al. 2009).

Reviews into dams and reservoirs similarly study the implications of climate change on infrastructure. The review into the Missouri reservoir examines the question of climate change, even though this issue is not technically within its scope. It suggests that the future regulation of the reservoir system should be adjusted to account for climate change and recommends incorporating greater flexibility in reservoir operation to adapt to climate extremes (of both drought and flood) (Grigg et al. 2011).

Recent reviews and papers on levees that were analysed for this report all include climate change as a factor that increases the likelihood of catastrophic consequences from flooding (ILPRC 2006; ASFPM 2007; Galloway, Boland et al. 2007; NCLS 2009). A large number of American levees, particularly those aiming to comply with National Flood Insurance Program requirements, have been built to protect against a 1 in 100 year flood event. With climate change, the reliability of this recurrence interval is in doubt, jeopardising substantial development that has been allowed to occur behind levees, or just beyond the mapped 1 in 100 year flood line.

As well as climate change, reports identify numerous other future flood-risk magnifiers. These include changing demographics, such as population pressure to develop areas with a high flood risk, increased run-off due to urbanisation, the construction of additional levees, subsidence, changing water channel conditions and the deteriorating condition of flood control structures. Of these, the continued development of floodplains is prominent. The Interagency Levee Policy Review Committee finds that the effects of increased development 'can increase damage to structures by multiple orders of magnitude' (ILPRC 2006). Larson reports that the impact of development can have a huge effect on flood levels. In New Carolina, a 2–9 feet (0.6–2.7 m) increase in flood depth was recorded in one area (Larson 2009). Review findings on the importance of appropriate siting of development are discussed later in this report.

The Interagency Levee Policy Review Committee argues that there needs to be a conceptual shift. Rather than reflecting present conditions, mapping criteria need to be based on 'possible but not fully quantifiable future conditions … this step must be taken' (p. 57).

Unlike Australian reviews, American flood reviews have changes to future flood threats in sight, and are not simply responding to the conditions that contributed to the last great flood event.

6.3.5 Structural approaches

The United States places strong emphasis on structural measures for flood control. A brochure produced by the US Army Corps of Engineers reveals a reliance on levees, reservoirs, pumping stations, channel works including revetment, cutoffs (cutting across the neck of meanders to speed drainage), dredging to deepen navigation channels, and groynes, as well as floodways to reduce pressure on levees (US Army Corps of Engineers 2009).

6.3.6 Dams

The United States has a National Dam Safety Program that provides for public safety through review, regulation, and standards for dams. A recent study reviewed the safety of dams in the United States (Galloway et al. 2011). The United States has a national inventory of dams, including 84 000 dams over 25 feet (7.62 m) high, or 50 acre-feet (~63 megalitres) capacity. Of these, approximately 32% are rated as being a high or significant hazard and 1819 high-hazard dams are considered deficient. Nearly half of the dams on the inventory are over 50 years old. The report identifies a number of emerging challenges for managing dams including:

- aging infrastructure
- increased rainfall intensity and larger floods due to climate change
- increasing population and development that may lead to development below dams and change their risk status
- changing functions of dams requiring new operating procedures
- lack of public understanding of dam safety risks.

Australian flood reviews – particularly the Queensland Inquiry – reveal concerns regarding the safety of some dams (see Section 4.1.1 of this report). Other studies into the safety of Australian dams also suggest that current provisions are inadequate. In Australia, owners have a common law responsibility to maintain small dams to accepted standards set by the Australian National Committee on Large Dams (ANCOLD), but compliance with these standards is an issue. Pisaniello (2010) reports considerable issues with farm dam safety, with dam failure rates as high as 23% posing significant threats to downstream communities. The common practice of deliberately blocking spillways to increase storage capacity is a contributing factor. Referring to a study of South Australia's Kangaroo Creek region, Pisaniello (2010) reports that 'most small dams cannot even pass the 1-in-100 years design flood event'. Like the United States, Australia may need to consider a review of dam safety, including the assessment of future threats such as population movements and increased inflows due to climate change.

Another American report, the *Review of the Regulation of the Missouri River Mainstem Reservoir System During the Flood of 2011,* examined the operation of six large reservoirs on the Missouri. During the 2011 floods, run-off was the biggest on record, 'far exceeding the flood storage capacity of the dams and reservoirs, overwhelming the floodplains, saturating and overtopping levees, and forcing hundreds of homeowners, farmers, and business owners to evacuate' (Grigg et al. 2011, p. 10). In common with the Queensland Inquiry into the Wivenhoe Dam, the review panel found that residents had believed that the dams would protect them from flooding. Faith in structural protection fosters a false sense of security that encourages development in flood-prone areas. Ultimately, this leads to increased flood damages when the capacity of these structures is exceeded. This is increasingly likely given the expectation of larger floods.

In common with Queensland Inquiry findings, the Missouri review identifies conflict between water supply and flood mitigation functions, concluding that 'additional storage may have lessened, but not necessarily prevented the 2011 flooding … the Corps needs to be given the flexibility to manage to changing, wetter conditions but also needs to be removed from reproach, if, after successive wet years, the following year turns out dry' (p. 7).

Other similar themes include a lack of guidance in manuals about how to deal with extreme flood events and the need for improved data collection, forecasting, modelling and decision support tools. The report also recommends better funding for maintenance of spillways and levees (Grigg et al. 2011).

Regarding climate change flooding, the report makes the point that basing flood storage requirements on an historical record that only dates back to 1898 is inadequate. When preparing Annual Operating Plans, 'the fact that recent decades have experienced more extreme events should be considered, rather than view the entire historical record as having equally likely chances of occurrence' (p. 4). The report recommends increased flexibility in the operational system to ensure that storage capacity is able to accommodate 'floods like 2011 or larger' (pp. 8, 54).

6.3.7 Levees

Levees are a very significant flood mitigation measure in the United States. From 1866 up until catastrophic levee failures during the 1927 Mississippi floods, America had a 'levee only' policy for flood control that deliberately excluded alternative options (Wright 2000, p. 5). While other measures such as floodways were later incorporated into flood protection for the Lower Mississippi Basin, levees have continued to play a significant role in American flood control. It is estimated that, today, 43% of the US population lives in a county with levees (ILPRC 2006). The United States is estimated to have 14 000 miles (22 530 km) of USACE levees that were either built by USACE or other non-federal agencies and integrated into the federal program for repair of flood damaged levees. There are an additional 21 000 miles (33,800 km) of levees that are considered part of the national flood insurance program and under federal oversight. The National Committee on Levee Safety estimates that there are a total of 100 000 miles (160,934 km) of non-federal levees and 8000 miles (12 875 km) of 'levee-like structures' along canals (NCLS 2009, p. 14).

The distinction between these levee categories is important as federal levees are significantly more reliable than non-federal ones. USACE boasts that since its inception in 1928, no project levee built to Mississippi Rivers and Tributary system standards has ever failed (US Army Corps of Engineers 2009). During the 1993 flood in the Upper Mississippi River basin, only 17.5% of federal levees overtopped or were damaged, as opposed to 77.4% of non-federal levees (NCLS 2009, p. 64). Levee failure or overtopping is implicated in about one-third of US flood disasters (ILPRC 2006, p. 11).

Levees have continued to be of importance partly because of the provisions of the National Flood Insurance Program (NFIP). For communities participating in the NFIP, areas outside the 1 in 100 year flood zone are not subject to mandatory flood insurance or development controls. This also applies to (otherwise flood-prone) land that is located behind levees designed to protect from the 1 in 100 year flood (Galloway et al. 2006). From a short-term development point of view, this makes it very appealing to construct levees. However, it has also resulted in accentuated flood risk, as will be discussed below.

In 2005, Hurricane Katrina hit New Orleans and the Gulf Coast. This resulted in 1800 deaths and $200 billion in damages, the most expensive natural disaster in the history of the United States (ILPRC 2006, p. 14; NCLS 2009, p. 12).

The New Orleans levees were expected to protect the city from floodwaters to the design height.[10] However, some of the levees and floodwalls failed before they overtopped. Problems were severely compounded by the city's poor drainage. While levees might keep floodwaters out, they can also impede natural drainage and trap water from rainfall within them. Water became trapped within the levees and needed to be pumped out, a task which took weeks to complete (ILPRC 2006) (p.14-15). Not only were levees inadequate but so too was pump capacity, which is unable to keep the city dry even during less severe rainfall events. Moreover, pumps require staff to operate them, which proved to be an issue due to the massive scale of the New Orleans disaster.

The level of protection afforded by the New Orleans Hurricane Protection System was somewhat low. According to the National Committee on Levee Safety, the overall protection was estimated to be at about the level of a 1 in 50 year flood (p.64). The USACE is currently spending $15 billion in order to repair the levees and floodwalls and to improve them so as to protect against a 1 in 100 year event. Most American studies recommend that urban areas should be protected against 1 in 500 year events (due to larger consequences of flooding in densely populated areas and greater evacuation difficulties), so upgrades to this level of protection may be inadequate.

Hurricane Katrina has resulted in a major reassessment of the role of levees in flood management. Reviews and reports on levees reveal innumerable issues, most of which are reiterated by multiple references. These are outlined below:

Levee technology ages

Federal-built levees in the United States are on average 50 years old. Non-federal levees can be 100 years old or more, and the engineering standards used to build them are out of date, leading the National Committee on Levee Safety to declare that levees are 'museums of the best practices of the past' (p. 16). The committee notes that serious design, construction and operational issues will cost 'billions of dollars and decades' to address (p. 38). Unlike non-structural measures that are long-term solutions, infrastructure ages and technology can become obsolete in only a few decades.

The techniques used to calculate required levee height also age. This is discussed in more detail in Section 6.3.8.

Levees deteriorate over time

Animal burrows, levee encroachments (e.g. sewer pipes may pass through them), natural or system-induced erosion, lack of maintenance, land subsidence and seismic activity can cause the profile and integrity of levees to deteriorate over time (Galloway et al. 2007, pp. 2, 10, 14, 22; ILPRC 2006, pp. 3, 21–2). Land subsidence was found to be a significant issue for New Orleans levees during Hurricane Katrina, and levees had 'sunk', providing less protection than they were designed to afford (USACE 2009, pp. 2, 26). In Australia, there have been similar examples of sunken levees (Atkins & Vince 2009). The possibility of levee deterioration adds a level of uncertainty about how levees will perform during an extreme flood event. In the United States, at least, there is inadequate data to be able to predict levee reliability (NCLS 2009, pp. 14–16; ILPRC 2006, pp. 39–42).

[10] There are two kinds of levees in New Orleans. The oldest and largest, with levels of protection in excess of 500 years, are those protecting New Orleans from the Mississippi River. These levees were initially built by the French in the 1700s, and have grown over time. Those built since 1965 are intended to act against hurricanes with recurrence intervals that have varied over time: less than 300 years theoretically and 80 years in reality (Galloway, pers. com.).

Catchment conditions change

Levees are built to protect against a design flood height. In the United States, levees built to comply with the NFIP requirements commonly aim to protect against the 1 in 100 year flood. However, catchment conditions can change the level of flood waters. Climate change can increase the amount of water in the hydrological system. Development can prevent infiltration of water into the soil and increase run-off. Levees (by preventing distribution of silt over the floodplain) can cause channels to silt up resulting in less channel capacity to hold and convey flood water. Levees built elsewhere reduce the area water can spread, causing deeper floods. Thus the original design height of a levee may soon become inadequate to protect against a flood of the frequency originally envisaged.

Consequences of levee failure are worse than natural floods

When levees fail, they do so with little or no warning, and the energy of floodwaters in the vicinity of the failure is high. This means that levee failure can cause significantly greater damage to lives and property than a natural flood. This is compounded by a false sense of security of those living behind levees, who feel safe because levees have protected them from lesser floods and so they have little experience of flood and are lacking flood preparedness skills. The lack of awareness of residual risk means that other measures, such as house elevation, flood proofing, and emergency and evacuation planning and exercises are frequently neglected (ASFPM 2007).

Levees offer less protection than elevation to the same height

As demonstrated by the Hurricane Katrina event, levees can fail before floodwaters reach the top of the levee. Levees also prevent drainage of water, which can cause floodwaters to be deeper behind levees and remain longer (USACE 2009, pp. 5, 41).

Even assuming a levee is reliable, the house protected by that levee (affording protection to the 1:100 standard) is significantly more vulnerable to flooding than a house elevated to the 1:100 level (Galloway et al. 2007, p. 19; ILPRC 2006, pp. 23–4, 55; ASFPM 2007, p. 3). As graphically demonstrated by the California review, a property protected by a (reliable) 1:100 levee may be safe from a 1:100 flood. However, depending on floodplain depth, a 1:105 year flood may completely submerge it. On the other hand, a property elevated to the 1:100 level will only suffer minor damage in a 1:105 flood and, unlike its counterpart behind the levee, will be more likely to be covered by mandated flood insurance. Ironically, the ASFPM suggests that a 99-year levee ensures much better protection than a 100-year levee as development and insurance restrictions will apply.

Levees encourage development of flood prone land

Land ‘protected’ by levees is perceived to be safe. This encourages further development behind levees, greatly magnifying damage costs when the levee fails (due to overtopping or breach). Increasing the height of levees may reduce frequency of flooding, but if development continues, the consequence of catastrophic failure will continue to rise. This has been the experience in the United States, with annual costs of flood disasters continuing to rise, simply because the ‘consequence’ part of the risk equation has been ignored. Interestingly, federal involvement in levee building has fostered the misperception in communities that levees are a ‘safe and prudent’ method of protecting against flood (ASFPM 2007, p. 9). It is estimated that $375 billion of residential and commercial assets (property and contents) are currently located in leveed areas in the United States (NCLS 2009, p. 63). As the damage bill of New Orleans was estimated to be US$200 billion, this is not necessarily indicative of the true costs of levee failure. Damage estimates rarely include all costs, such as emergency services, levee repair, utility infrastructure, evacuation, lost business and income, social disruption and other indirect costs (Galloway et al. 2007, p. 5).

Levee construction is expensive

Discussing the benefits of levees, the NCLS report quotes a USACE figure showing that the average USACE levees provide a 6:1 return on investment on flood damages prevented, while for Mississippi River and Tributaries levees, the figure is 24:1 (p. 13). These figures represent flood damages prevented versus *initial* costs, and as discussed in this section, levee construction is only the beginning of substantial levee expenses.

Levee costs vary according to project, but are generally expensive and unaffordable for local communities. Projected costs for a USACE levee construction project in the Vicksburg District totalled US$3.2 million per mile to upgrade existing levees from 2 feet to 9 feet (0.6 m to 2.7 m). Fowler (1996) explains some of the reasons for these costs: 'a major obstacle to raising the levees is economics with the local levee boards trying to budget money for their cost shared amount. The major cost involves obtaining real estate for borrow areas for levee fill material.' The Vicksburg levees are more expensive than most but there are similar local affordability issues in Australia. Due to repeated flooding and insurance losses in the town of Roma, insurer Suncorp has demanded that levees be built. This has led to requests by Roma's mayor for federal government funding, as the A$15 million bill is beyond the capacity of the town to pay (Jabour 2012).

The National Committee on Levee Safety reports that *adequate* management of risk using structural means, as exemplified by the Netherlands, is prohibitively expensive (NCLS 2009, p. 15). The federal government first became involved in levee building following the 1927 Mississippi floods. Federal agency USACE has been responsible for the majority of federal levee building and for a long period of time used the 'standard project flood' to guide its flood-protection activities. This is not a measure based on return periods, but generally lies between the 1 in 200 and 1 in 500 year flood.[11] Many of these levees were very robust and protected against the 1 in 500 to 1 in 1000 year flood (Galloway et al. 2007, pp. 15–16; NCLS 2009, p. 9). In 1986, the *Water Resources Development Act* introduced a requirement for communities to share the costs of levees built by federal agencies. Even the cost share amount of 35% can be hard for local governments to afford, and this resulted in projects that only met the minimum requirements of levee protection (to the 1 in 100 year level) and *ad hoc* localised levee building instead of basin-wide systems (NCLS 2009, p. 11).

The reason the 1 in 100 year level became so widely used was that this was the minimum required for recognition by the National Flood Insurance Program (NFIP), 'a dangerous adoption of an actuarial standard as a safety standard' (NCLS 2009, p. 11). This created perverse incentives for lower standards of levee building and encouragement of floodplains development (see Section 6.3.9). According to the National Committee on Levee Safety, the majority of American levees (with some exceptions, such as the Mississippi Rivers and Tributaries project) provide inadequate protection (p. 15).

Another expense issue contributing to lowering standards has been the application of the 1983 US Water Resources Council 'Principles and Guidelines' to all water resource projects developed by the US Bureau of Reclamation, TVA, USACE and the US Natural Resources Conservation Service (NRCS). They are also used by many state agencies. While environmental and social objectives are technically part of the assessment, economic considerations take precedence and cost-benefit analysis of flood protection activities needs to be conducted to demonstrate that federal projects contribute to

[11] According to the California Review, the Standard Project Flood is a 'derived discharge' estimate, representing a flood that can be expected from the *most severe* combination of meteorologic and hydrologic conditions that are considered *reasonably characteristic* of the region and must be developed for the specific watershed under consideration (Galloway et al. 2007, pp. 15, 18).

national economic development (NED). This has made it very hard to achieve approval for projects that afford protection greater than the 1 in 100 flood level. Critics argue that NED and cost-benefit analysis omit or underestimate important indirect or non-economic costs and benefits (ILPRC 2006, p. 29; ASFPM & NAFSMA 2007; Freitag et al. 2009, pp. 150–1; Galloway et al. 2007, p. 5). The *Water Resource Development Act 2007* required a shift from sole reliance on NED to include life safety, environmental and other issues. However, guidelines have not yet been issued for its implementation (Galloway, pers. com.).

Levee certification is expensive

In the United States, levees need to be inspected and certified as providing protection to at least the 1 in 100 year flood in order to be eligible to qualify for NFIP levee provisions. A certified levee can then be given accreditation by FEMA, the organisation that administers the NFIP. It is believed that only a fraction of levees certified to provide protection to the 1 in 100 year standard actually do so (ILPRC 2006, pp. 8, 55).

When levee certification was first introduced, certification was commonly granted on the basis of crown height alone, with little or no consideration of other factors such as structural stability or maintenance plans, and many of these levees are still mapped and credited as providing adequate flood protection despite never having been measured against current NFIP levee standards. The ILPRC reported that at the time of writing, certification did not include all aspects of levee function, such as drainage and pumping capacity, though the most recent version of the Code of Federal Regulations includes drainage lines and pumping (FEMA & DHS 2011, pp. 2969). Due to considerable issues with levee deterioration, all levees now need to be re-evaluated. Depending on the levee, this could cost more than $100 000 per mile (1.6 km) (ILPRC 2006, pp. 9, 24, 58).

There is currently no mechanism for periodic reaccreditation of levees. The Interagency Levee Policy Review Committee recommends that recertification occur every 10 years, and that levee sponsors inspect annually and provide inspection reports and operation and maintenance records to FEMA every two years (ILPRC 2006, pp. 24–5).

Inspection and certification require local resources and expertise, and liability concerns are reducing the availability of these services. It is likely that re-evaluation requirements will result in levees being decertified, and this can have an enormous economic impact on communities, which are already turning to the federal government for support (ILPRC 2006, 43–7).

Levee maintenance is expensive

In the United States, the federal government will agree to pay 65% of the costs to design and build levees. However, inspection, certification, maintenance and operation are the responsibility of the local sponsor, usually a local government. The ASFPM notes that there is currently no requirement for local sponsors to demonstrate they have the technical or financial ability to undertake these commitments prior to the levee being built. These activities are an ongoing burden for local communities and maintenance is often inadequate (NCLS 2009, p. 11; Larson 2009, p. 11). While levee reviews do not provide an indicative figure for maintenance costs, rigorous maintenance requirements are provided in the USACE levee owners' manual (USACE 2006).

Levee repair is expensive

Following floods, the federal government funds 80% of repair costs of levees that are eligible under the USACE emergency flood control repair program. Of approximately 1600 levees damaged during the 1993 flood in the Upper Mississippi River basin, fewer than 500 met eligibility criteria (Wright 2000, pp. 75–6). Levees that were eligible tended to be those that were large and expensive.

In the State of California, it has been estimated that costs to repair and improve levees and other flood protection across the state would be US$30 billion. Following Hurricane Katrina, costs to repair and upgrade New Orleans levees and floodwalls to the 1 in 100 year standard have been budgeted at around US$15 billion (NCLS 2009, pp. 55, 64).

Levees are a liability

Litigation can be considered a source of recovery funding. However, it is inefficient in terms of both time and expense, and outcomes are uncertain (Galloway et al. 2007, Appendix B). While federal agencies have been granted immunity from liability for damage from floods, state and local governments and private engineering firms are exposed to liability risks when they design, build, inspect, certify, maintain and operate levees (or provide funding to do so). Potential liability costs far exceed the value of fees for services or even the entire financial value of a private engineering firm. This has reduced availability of these services, and may compromise participation in the new National Levee Safety Program. These liability concerns are real, as demonstrated by the 2003 *Paterno* decision that held the State of California liable for levee failure (NCLS 2009, pp. 16, 39–40). Arguably, structural methods of flood control are more vulnerable to lawsuits than non-structural and ecosystem approaches.

Levees require strong investment in administration

American levee reports make it evident that rigorous administration is needed to ensure good management of levees. Problems with levee safety during Hurricane Katrina resulted in the federal government passing a new *National Levee Safety Act* in 2007, to be implemented through a National Levee Safety Program. However, there has been no action on the National Levee Safety Program in the last five years (Galloway, pers. com.).

A significant failing of the New Orleans Hurricane Protection System was that no single agency or body was responsible for providing oversight of the system, which resulted in overlapping roles, responsibilities and accountabilities. This caused significant problems for decision-making and contributed to the failure of the system to function effectively (Galloway et al. 2007, pp. 23, 36). Another significant issue was the lack of a systems approach to the protection works: 'It is obvious from the IPET analysis that the piecemeal development of the New Orleans Hurricane Protection System provided a system in name only.' (USACE 2009, p. 127) The USACE report recommends that planning and design need to allow for system-wide performance over time, including all components of the system, such as pump capacity.

Levee building in river basins is not coordinated. Levees are built by all levels of government and private interests to different standards. They are maintained and operated independently (Freitag et al. 2009). A systems approach is widely recommended by most reviews, not restricted to the city scale. The NCLS review recommends that flood protection needs to be designed as a complete system that analyses how the combination of structural measures and floodplain management measures perform together across entire basins (pp. 17, 22–3), as do the California Review (p. 22) and the Interagency Levee Policy Review Committee (p. 57). This requires consideration of physical and political systems rather than individual reaches. A systems approach is also a key concern of the International Joint Commission in its review of provisions for the Red River, which crosses the US border into Canada. The IJC recommends that structural and non-structural flood mitigation be integrated on a basin scale, and that there be ongoing support for multi-jurisdictional participation (IJC 2000).

Although the United States already has a National Levee Database, basic information about levees is lacking. The National Committee on Levee Safety reports that 'the

number, location and condition of all the levees in the US is currently unknown' (p. 14).[12] The committee proposes to expand the existing database by undertaking an inventory and assessment of all the nation's levees, including both federal and non-federal levees regardless of their level of protection. A report prepared for FEMA lists proposed inclusions of the expanded database. These include levee condition, the area protected by levees and its flood zone, certification status, ownership, the level of levee protection and risks associated with levee failure. This information is needed for prioritisation and decision-making relating to levees (ILPRC 2006, Appendix E). It will also require ongoing inspections and reporting from local governments or levee sponsors.

As well as inadequate information on the status of US levees, the NCLS notes that there are no national levee policies, standards or best practices relating to levee safety, resulting in wide-ranging risk profiles. This lack of risk management compromises public safety and economic security. As well as introducing national policies and standards, the NCLS recommends the development of Tolerable Risk Guidelines to improve decision-making. Similar in approach to the Netherlands, this would place an economic value on life saved, and would address social equity, looking at both individual and societal risks as well as cost effectiveness (pp. 36–8). To date, no action has been taken to implement the NCLS recommendation (Galloway pers. com.).

Presenting similar issues, the Interagency Levee Policy Review Committee argues for a scientifically based levee risk classification system. The system would include aspects such as the water depth in the event of overtop or breach, the density and type of development, steps taken to ensure failure does not occur and warning times and evacuation provisions (pp. 11, 24).

To fund issues relating to levee safety, a National Levee Rehabilitation, Improvement, and Flood Mitigation Fund is proposed as part of the National Levee Safety Program. As well as establishing national safety standards and an inventory, the fund would provide funding for levee research, training programs in levee safety and public education. State roles would be to implement and oversee levee safety programs. To ensure participation in the National Levee Safety Program, the NCLS and the California Review propose a range of incentives and disincentives (NCLS 2009, pp. 46–7, 51–5; Galloway et al. 2007, p. 27, Appendix C). Appropriate roles, responsibilities and accountabilities for different levels of government in flood control are presented by the California Review. This could have relevance to Australia as, in common with the United States, land management is primarily a state and local government responsibility.

Levee protection is very important for many Australian country towns. However, Australian state and federal governments have been reluctant to fund levees in the past (Smith 1998, p. 232). Australia therefore relies less upon levees than America. Levee administration is also less developed, with ownership of (and maintenance responsibilities for) some levees in hot dispute (Gannawarra Shire Council 2011) and no regulation of levees in many areas of Australia (Queensland Inquiry final report, pp. 168–72). If Australia decides levees are an appropriate measure to prevent future flood damage, it will need to set up rigorous administrative systems to ensure the risks of flooding are not magnified.

Levees hurt others

Levees have impacts on other floodplain communities. By straightening channels, removing blockages and reducing the area water can spread, levees can increase floodwater velocity and depth, and can transfer flooding elsewhere (Smith 1998; Freitag et al. 2009; Larson 2009, p. 11). This is not an equitable solution.

[12] According to Professor Gerald Galloway, the levee database now has good information about USACE levees, moderate information about NFIP levees and none about other levees.

Levees degrade natural resources

Levee reviews report considerable concerns about environmental impacts. Issues include the decline of riparian flora and fauna; declining river health; degradation of estuarine wetlands due to reduced sediments reaching them; reduced water quality; and increased erosion due to the power of confined floodwaters. These effects not only damage ecosystems, but impact on natural resource dependent industries and recreation (Galloway et al. 2007, pp. 26–7, Appendix D; NCLS 2009, pp. 15, 46; Larson 2009, p. 10).

One reason levees do so much harm is that they are often built very close to river banks and have to be kept vegetation-free for maintenance purposes. The USACE manual outlining levee maintenance requires levees to be kept completely free of shrubs and trees. Any trees with trunks greater than 2 inches (5 cm) diameter need to be removed, along with their root balls. Levee tops and sides need to be kept mown to enable visual inspection. Fertilising and watering are required to promote good sod cover and encroachments such as livestock must be excluded. A vegetation free zone of 15 feet (4.5 m) is required beyond the toe of the levee (USACE 2006, pp. 16–17). A functioning riparian habitat is clearly not possible under these management requirements if levees are located close to river banks on both sides of the river. Removal of vegetation can also result in water quality issues, as it becomes easier for contaminants to enter waterways.

USACE maintenance requirements conflict with endangered species and environment legislation as well as water quality regulations. However, if maintenance requirements are not complied with, local sponsors risk losing considerable financial support. The USACE vegetation removal policy was renewed and rigorously implemented following Hurricane Katrina, and has received considerable backlash from local governments (BAFPAA n.d.; CSAC n.d.).

A better use of levees

Reviews, academics and organisations all emphasise the limitations of levees for flood protection. The ASFPM describes levees as a method that should be used as a *last resort* for *existing* development (ASFPM 2007, p. 1). Freitag et al. (2009), who have written a text for a FEMA graduate course in floodplain management, write that 'discouraging the use of levees as a flood-control measure is a major theme of this book. The long-term costs in money, lost natural resources and catastrophic failures are unsustainable.' (pp. 46–7) The California Review argues that avoiding flood risk through development controls and regulations should be the first line of defence, and that levees and other structural measures should be secondary (Galloway et al. 2007, p. 13).

Levee reviews looked at in this section point to a reliance on levees and an under-use of non-structural measures, such as development controls, building codes, levee safety programs, emergency evacuation, flood warning, risk awareness and insurance (NCLS 2009, p. 15; Galloway et al. 2007, pp. 13, 25, 31; ILPRC 2006, pp. 24, 50; IJC 2000, p. 2; Committee on New Orleans Regional Hurricane Protection Projects 2009, pp. 26–31). If levees are chosen as the appropriate solution, reviews and other sources point to a number of ways in which their use can be improved:

- Levees protecting urban areas need to provide a higher standard of protection, as the consequences of catastrophic failure in densely populated areas are too high and evacuation of such areas is difficult to accomplish quickly. Most recent US reviews and other sources suggest urban levees should be designed to the 1 in 500 year event, though some make the point that this is also arbitrary and that, regardless of the level of protection, levees cannot be relied upon in the

absence of other measures (Galloway et al. 2007, pp. 17–18; ILPRC 2006, p. 56; NCLS 2009, p. 12).

- Areas protected by levees should be subject to additional measures, including mandatory flood insurance, warning and evacuation plans and periodic notification of owners, tenants and lenders of potential risks[13] (ILPRC 2006, p. 11; Grannis 2012, pp. 10–11).
- Rigorous administration and a system approach are needed to ensure levee safety (see levee administration, above).
- Levee design can be improved. Incorporation of spillways at strategic points where there is lower density development can enable safe overflows when floodwaters exceed design height, preventing catastrophic levee failure (Galloway et al. 2007, Appendix C; ASFPM 2007). Levees can also be designed so they have the flexibility to accommodate modular improvements if future conditions change (Galloway et al. 2007, pp. 26, 30). Adverse impacts of levees and development need to be evaluated before project approval and plans to mitigate these should be incorporated (ASFPM 2007).
- Levee setback is a method that can considerably reduce the negative impacts of levees. Levee setback means the levee is placed further away from the river, allowing for more natural meandering and establishment of riparian habitat. This 'room for rivers' strategy can reduce flood height and velocity, which in turn can reduce operation and maintenance demands. Levee setback increases the 'operational flexibility' of the water management system by incorporating greater redundancy. Another advantage of levee setback is that it enables a multifunction approach so that flood damage reduction can be combined with community open space, recreation, water quality and supply, and provide habitat for environmental objectives. Multifunction approaches tend to attract broader public support (Galloway et al. 2007, pp. 26–7, 30–4, Appendix D; Freitag et al. 2009, pp. 98, 106, 157; Wright 2000, pp. 73, 84).

The US experience with levees is very different to that in the Netherlands. It seems likely that this is because the United States is preoccupied with flood frequency while the Netherlands is more concerned about the potential consequences of severe flood events, which can cost much more than putting in place adequate prevention measures. High population density also means that the costs of constructing sufficiently robust levees and dykes are shared by a greater number of people in the Netherlands (466/km^2) than in more sparsely populated countries like America (36/km^2) or Australia (2.5/km^2). However, even the Netherlands recognises the limitations of dykes for flood protection and is implementing levee setback programs.

Levees have played such a prominent role in US flood protection that the problems of relying on this method are now clearly visible. It is perhaps fortunate that Australia has been less able or willing to afford levee protection to date, so it has fewer legacy problems to resolve. Nevertheless, significant lengths of levee (or de facto levee such as irrigation channels) have been built on Australian floodplains, many entirely unregulated. Lessons can be learnt from the United States about how to manage existing levees, and their appropriate role in floodplain management as a costly measure of last resort.

6.3.8 1:100 flood standard and development controls

Flood frequency analysis was pioneered in the United States by the Tennessee Valley Authority, a federal water resource development agency that operated in the Tennessee Valley Basin. The TVA developed two hypothetical floods, the 'maximum probable' and the 'regional'. The latter was based on the largest known flood within 60–100 miles (96–

[13] Residual risk provisions in the Flood Insurance Reform Bill were strongly opposed and were removed in order for the *Flood Insurance Reform Act (2012)* to be passed.

160 km) of the stream being studied, and this became a key development tool for the basin until the mid-1970s (Wright 2000, pp. 16–19, 48).

An alternative method based on average return interval was later developed by the Water Resources Council, and in 1966 the Council published its first guide for determining flood flow frequencies. The second revision, published in 1981, is the standard guide used by government agencies today (Wright 2000, p. 42).

The 1 in 100 year flood was selected as an actuarial standard for the purposes of implementing the National Flood Insurance Program in 1971, and its effect has been to concentrate development just beyond the limits of the 1 in 100 year event. The selection of the 1 in 100 flood was arbitrary, and was not based on 'sound scientific and scientific statistical foundations'. Rather, it represents a compromise that balances flood losses against excessive floodplain regulation (Galloway et al. 2006; Wright 2000, pp.25, 71; Hirsch et al. 2004, p. 117). This is of relevance to Australia, as most planning schemes have followed America's lead in adopting the 1 in 100 flood as a development tool. An excellent explanation by Gilbert White and the National Research Council about the selection of the 1 in 100 standard is reprinted in the National Committee on Levee Safety report (NCLS 2009, p. 10).

Accuracy of the 1 in 100 event

American sources reveal considerable issues with the accuracy of the 1 in 100 year standard. Far from being stable, it is riddled with uncertainties:

- *Short term records.* There is a lack of long-term baseline data for precipitation and runoff in the United States – often less than 100 years. Moreover, observational methods have changed, and it is hard to assign flow rates and flood depths to past events. If flood records extend back 100 years, flood estimates that are extrapolated from this data should not exceed 200 years (Galloway et al. 2007, p. 14; Wright 2000, p. 74; Nott 2006).
- *Out-of-date data.* Baseline information used to determine the 1 in 100 year event is out of date by up to 45 years. Data generated more than 10 years ago generally provides an inadequate description of today's conditions (ILPRC 2006, pp. 33–7; Galloway, et al. 2007, p. 22).
- *Floods lead to recalculations.* The 1 in 100 flood is determined on past flood records. Any subsequent severe flood will add to this data and recalculations after such events have shown earlier flood frequency calculations to be incorrect. This was the case after the 1993 flood in the Upper Mississippi Basin (Galloway et al. 2007, p. 15).
- *Improved techniques.* Calculation techniques and data collection improve, and this also leads to revisions of the 1 in 100 flood. In the lower Missouri River, flood heights for the 1 in 100 year event were recalculated as being 4 feet (1.2 m) higher in some areas and 2 feet (0.6 m) lower in others (ILPRC 2006, p. 4).
- *Based on assumptions.* The methods by which flood magnitude is predicted (flow frequency analysis, regional regression equations and design storm runoff models) all incorporate assumptions and use imperfect data (Larson 2009, p. 10; (Grigg et al. 2011, pp. 4–5).
- *Future conditions.* Future changes such as development and climate change alter a catchment's hydrological conditions. This means that what was once a 1 in 100 year event may now be a more frequent occurrence. In the case of one basin, development caused a seven-year event to become an annual one, and what was once a 1 in 100 year event now occurs 1 in 25 years (Larson 2009, p. 10; Galloway 2009, p. 6; Freitag et al. 2009, pp. 44–5).

- *Under-estimates of magnitude.* 'The general trend for flood flows [is] to be greater than anticipated.' (Galloway et al. 2007, p. 11). Streamflow data recorded for the Missouri River since 1898 indicate nine out of the top 10 records for highest runoff have occurred in the years following 1975 (Grigg et al. 2011, pp. 54–5). Such findings are not confined to a single basin (Galloway 2009, (p. 6).

To address uncertainty relating to precipitation frequency estimates, the National Weather Service has started to publish estimates of uncertainty for different localities. The Interagency Levee Policy Review Committee found these estimates make it clear that real uncertainties exist: 'uncertainties are on the order of plus or minus 25 percent in the upper and lower 90-percent confidence intervals in extreme cases' (ILPRC 2006, p. 34).

While the 1 in 100 year flood gives a pleasant impression of certainty, this is not the case. Whether it be due to imperfect data, urbanisation or climate change, the 'line on the map' can move. Reliance by planners on a standard that is too low can place many people at unacceptable risk from flooding.

Difficulty in determining the 1 in 100 flood line is not a problem unique to America. Uncertainties regarding Brisbane's 1 in 100 year flood line, for example, were identified in the final Queensland Inquiry, with estimates ranging from 3.16m to 5.34 m at the city gauge. One of the reasons the earlier 5.34 m calculation was not accepted was that a review of the methodology disagreed with the assumption that Wivenhoe and Somerset Dams would be at full supply level at the start of a flood and that no water would be lost to the ground (Queensland Inquiry final report, pp. 48–51). This is a strange assumption to discard as, according to dam operational manuals, 'a flood is taken to commence when the dam reaches prescribed levels above the full supply levels' (Queensland Inquiry interim report, p. 38). Moreover, at the start of the 2010–11 floods, catchments were already saturated, so little water would have been lost to the ground (Queensland Inquiry interim report, p. 20). While there were other concerns with the 5.34 m estimate, this demonstrates the part that assumptions can play in establishing an accurate 1 in 100 year flood line.

In another Australian example from Wagga Wagga, a flood study conducted in 2004 determined that the 1974 flood, which had previously been considered a 1 in 90 year event, was actually a 1 in 60 year event (Askew 2009). Thus existing CBD levees provided a lower level of protection than anticipated. In March 2012, these levees came within centimetres of breaching. To upgrade the CBD levee system to protect against a 1 in 100 year event, and the restoration of North Wagga levees to the 1 in 20 year level, is estimated to cost $20 million (Wagga Wagga City Council 2012).

Flood map inaccuracy has become a significant problem. Some 20% of repetitive losses occur outside the designated 100-year floodplain, a clear indication that the 1 in 100 year lines marked on current US federal flood insurance maps are likely to be inaccurate (NWF 1998, p. 58). FEMA recently established a committee that, among other things, was asked to examine factors that affect flood map accuracy. To this end, the committee produced a report, *Mapping the Zone: Improving Flood Map Accuracy*, which attributed most of the inaccuracy to the use of low-resolution mapping. The use of LiDAR is likely to improve this situation (Committee on FEMA Flood Maps 2009). Another report by the Interagency Levee Policy Review Committee looks at FEMA flood maps and zones in the context of levees (ILPRC 2006).

According to the California review, it is important for flood maps to map the distribution of risk (noting that depth is correlated with degree of damage). Simply marking a flood's extent is not sufficient. Further, the report argues that maps need to include both current

and future development, including inhabitants, structures and infrastructure, as well as current and future consequences of flooding (Galloway et al. 2007, pp. 23–4).

The appropriateness of the 1 in 100 year standard as a development tool

Many authors point out that the 1 in 100 year flood was never intended to be a safety standard, and that it is inadequate for this purpose. The degree of protection it provides is not consistent with other safety standards, such as those for fire, dams, aircraft and nuclear power plants. According to the ASFPM, using the 1 in 500 year flood would move flood hazard management closer to current standards for fire safety (ASFPM 2007, pp. 4–5).

The appropriateness of the 1 in 100 year flood as a development tool has also been questioned on the basis of statistical analysis. The National Committee for Levee Safety does this by converting floods of different recurrence intervals to the average 30-year mortgage. If using the 1 in 100 year flood, a person would have a 26% chance of experiencing a flood of that magnitude over the life of the mortgage, which is unacceptably high. It is only when a property is sited at the 1 in 500 year flood line that the risk of being flooded during a 30 year mortgage reduces to a more acceptable 6% (NCLS 2009, p. 12). This assumes the line on the map remains stable during the 30-year period.

Some sources note that 30% of flood damages are for properties outside the 100-year floodplain, mostly in the zone between the 1 in 100 year and 1 in 500 year flood lines (Galloway et al. 2006). Whether or not this is because the mapped 1 in 100 year flood zone is no longer correct, this indicates that the use of the 1 in 100 year event is inadequate for applying development controls, and the use of the 1 in 500 event may be more appropriate.

All reports studied find the 1 in 100 year flood event inappropriate as a planning tool for densely populated urban areas. This is partly because evacuation can be harder to achieve quickly in urban areas, and partly because the consequences of urban flooding are higher in terms of damages (though, as ASFPM points out, there are social equity issues with applying different standards for purely economic reasons). Most advise using the 1 in 500 year flood event for urban centres, though some favour using the Standard Project Flood (an explanation of this term is found in the section on levees) (ILPRC 2006, pp. 11, 55–6; Galloway et al. 2007, pp. 14–18; NOLA 5th report, pp. 5, 17; Committee on New Orleans Regional Hurricane Protection Projects 2009, p. 6; ASFPM 2007, pp. 4–5). The 1 in 500 year flood event is just as arbitrary as the 1 in 100 year standard, but it provides a greater margin of error of use for adapting to future uncertainties such as climate change and continuing development.

Problems with using the 1 in 100 year event as a ‘blanket’ criterion are also mentioned by some sources, with the consequences of flooding not necessarily reflected by a simple line representing areal flood extent. In some areas, a 1 in 100 flood may be relatively shallow, and the difference between it and a 1 in 500 year flood only a matter of centimetres. If the terrain is flat, a flood may be weeks in coming, giving ample warning time to move valuables and prepare. In steeper, more confined catchment, a 1 in 100 event may be deep and occur with little warning (Galloway et al. 2006; NCLS 2009, p. 10). Consequences need to be assessed for each area rather than selecting a standard simply because it is administratively easy to apply. According to the BTRE, the difference between a 100-year flood level and the probable maximum flood can be measured in centimetres for most NSW floodplains. Thus adapting to higher flood frequencies may only require minimal adjustments – for example, of floor height requirements in many areas of Australia (BTRE 2002, p. 57).

All reviews, including the USACE review into Hurricane Katrina (noting that USACE is the federal agency primarily responsible for levee design and construction), find that appropriate development siting and building codes are of key importance for reducing flood damages (NCLS 2009, p. 15; Galloway et al. 2007, pp. 13, 25, 31; ILPRC 2006, pp. 24, 50; IJC 2000, p. 2; Committee on New Orleans Regional Hurricane Protection Projects 2009, pp. 26–31). The selection of the right planning tool to achieve this is crucial. Due to uncertainties inherent in determining the 1 in 100 flood line, it seems prudent to allow a margin of error in case the line moves. This is more critical in areas where the difference between floods of different frequencies is great and in areas subject to high levels of future development. Queensland Reconstruction Authority flood maps that combine data from historical flood events with evidence of flood extent from the geological record compensate for Australia's short-term records and have great potential to increase awareness about the true extent of Australia's floodplains. In the light of significant flood damage to urban centres like Brisbane, Australia should also reconsider how appropriate the 1 in 100 standard is for urban areas.

6.3.9 The National Flood Insurance Program (NFIP)

The United States introduced a federal-backed insurance scheme in 1968 under the *National Flood Insurance Act*. The intention was 'to return cost for location decisions back to the landowner', as – despite considerable federal expenditure on structural flood protection – annual flood losses had continued to grow. The program offered insurance to those living within the 1 in 100 year floodplain, provided floodplain mapping to enable the program's implementation and offered an incentive for the use of development controls in flood hazard areas (Wright 2000, pp. 31, 34).

Participation in the national flood insurance program was initially voluntary, but became pseudo-mandatory when the government introduced the *Flood Disaster Protection Act* in 1973. This prohibited federal agencies from providing communities with assistance in floodplain acquisition or construction unless they participated in the program. These provisions also applied to 'financial institutions regulated or insured by the federal government, thereby covering virtually all types of financial assistance' (Wright 2000, p. 35). The 1973 Act was followed by the Brooks Amendment of 1974, which established the 100-year flood as the standard for NFIP recognition of levees (ILPRC 2006, pp. 9–10). The NFIP was not a trivial undertaking. Wright notes that barring social security, flood insurance represents the largest potential demand on the Federal Treasury (p. 41).

In effect, while land-use planning is a state and local government responsibility, the National Flood Insurance Program has enabled federal involvement in development control through the provision of incentives. Those who voluntarily participate are subject to mandatory provisions, and in return receive flood insurance.

In Australia, the federal government is undertaking its first attempt at facilitating improved land use. The Standing Council on Police and Emergency Management, made up of Commonwealth and state government ministers, is currently considering the 'Enhancing Disaster Resilience in the Built Environment Roadmap' to improve the consideration of natural disaster hazards in land use and building code regulation (Attorney-General's Department 2012a).

Problems with the NFIP

An evaluation of the NFIP was conducted between 2001 and 2006. Its 16 reports cover aspects such as the adequacy of the 1 in 100 year flood standard, community compliance, building standards, impacts of the program on development and the environment, as well as specific insurance issues such as mandatory insurance purchase and actuarial soundness.

The NFIP has been widely criticised for creating a perverse incentive that encourages development in flood prone areas. The NFIP's adoption of the 1 in 100 year flood event to determine where to apply mandatory insurance requirements and development controls has resulted in development that clusters just outside the mapped 1 in 100 year flood line.

Leveed areas are also exempt from these requirements (if certified as designed to withstand a 1 in 100 year flood). This has resulted in levees being built for the express purpose of excising land from the official floodplain to avoid insurance and development control encumbrances. Thus developers can build properties to lower and cheaper standards to maximise short term economic returns, while local governments can increase their tax base or achieve higher rates from newly 'protected' more valuable land. However, development of flood prone land, whether behind levees or on 'unprotected' land not subject to building standards, increases the future consequences of flooding (NCLS 2009, p. 20; Wright 2000, p. 71).

Insurance can be a perverse incentive in itself, as flood losses can be recouped (Freitag et al. 2009, p. 197). This can discourage the implementation of other flood-mitigation measures such as improved building standards and floodproofing. In the case of repetitive flood damage, cumulative insurance payouts can exceed the value of a property many times over.

The NFIP's adoption of the 1 in 100 year event has caused a considerable weakening of standards of levee building and, in some areas, a weakening of development controls. Prior to the NFIP, levee construction was much more robust and federal levees were built to withstand much higher levels of flooding, generally around the 1 in 500 year event and sometimes as high as the 1 in 1000 year event. The introduction of cost-sharing requirements for levee construction in 1986 meant that local governments, being less able to pay, opted for levees to be built to the minimum standard that would meet NFIP requirements, the 1 in 100 year event (NCLS 2009, pp. 9, 11; Galloway et al. 2007, p. 16). Some $375 billion of structures and contents are estimated to be protected behind levees in America, representing a considerable exposure to risk. Only 10% of structures behind levees have flood insurance and most of these are not covered to the complete value of the property (NCLS 2009, p. 63).

Wright provides an example of the regression of development planning that occurred after the NFIP was first introduced. The Tennessee Valley Authority had established the 'regional flood' as the tool to determine where development should be sited. This was based on the largest known flood within 60–100 miles (96–160 km) of the stream being studied. When the NFIP was implemented, the 1 in 100 flood was found to be lower than the regional flood. Despite advice from the TVA, the lower standard was almost universally adopted by local officials (Wright 2000, pp. 48–9).

Yet sources make it clear that the 1 in 100 event is insufficient to protect from flooding. Some 33% of flood damage occurs due to floods that exceed the 1 in 100 year event (Galloway et al. 2006). This exposes the federal government to considerable disaster relief and recovery costs.

The NFIP review recommends that mandatory insurance and development controls be extended to the 1 in 500 year floodplain to give a clear signal of flood risk (Galloway et al. 2006). Currently, there is no distinction made for insurance purposes between areas protected by levees and unprotected areas of the floodplain with low risk (e.g. within the 500-year floodplain or areas of the 100-year floodplain with shallow flood depths) (ILPRC 2006, p. 18). Rather than being a fixed standard rate, mandatory insurance rates need to reflect the level of residual risk (Galloway et al. 2007, p. 28).

Many other suggestions have been made to further improve the NFIP, such as incorporating future scenarios and encouraging the use of catchment-wide management and ecosystem approaches (Galloway 2009, Freitag et al. 2009, pp. 47, 205–6).

Advantages of the NFIP

While there are problems with the way in which the NFIP was implemented, it has also had considerable successes. The NFIP was the first introduction many communities had to land-use regulation and building codes, and even today the NFIP's Flood Insurance Rate Maps (FIRM) are the only hazard mapping available to most communities (Wright 2000, p. 37; ILPRC 2006, p. 3).

The NFIP, as well as promoting the use of non-structural forms of flood control, has evolved over time to incorporate incentives and address deficiencies. One of these is the Community Rating System, which was introduced in 1990. It provides insurance premium reductions of up to 45% for communities that are doing more than the minimum to protect against flood losses (Wright 2000, p. 39). The recent review of the NFIP suggests that, as well as providing incentives on a community scale, the CRS needs to provide incentives to individuals.

Reforms of the NFIP following the 1993 flood provided for the provision of mitigation insurance. This provides supplementary insurance payouts that enable rebuilding activities to comply with current building code standards. Eligible expenditure includes the cost of elevating, demolishing, floodproofing or relocating substantially damaged buildings (IFMRC 1994, pp. 124–5; Wright 2000, p. 82).

Another reform introduced at the same time required that substantially damaged properties (50% of building value or more sustained in a single event) be elevated to the 100-year flood level or removed from the flood hazard area. This also applies to repetitive loss structures, where cumulative losses of two events over 10 years are equal to or greater than 50% of the property's value. Communities participating in the NFIP are required to include these provisions in their planning regulations and enforce them (NWF 1998, pp. 53–4, 57).

Australia's recent National Disaster Insurance Review recommended that Australia adopt mandatory flood insurance, and that this be subsidised by the Commonwealth government. This recommendation was not accepted. In view of the potential for perverse incentives to occur if inexpertly implemented, coupled with the potential for huge demands on the federal Budget if not actuarially sound, there are good reasons for Australia not to go down the same path as America. However, there is potential for elements of the NFIP to be adapted for use by Australia's insurance industry which over time could reduce the damages insurers are liable to pay. This would require insurers to have a pro-active, long term view of risk management.

6.3.10 Disaster relief and mitigation funding

In the United States, disaster relief is primarily a local responsibility. The American federal government became involved in disaster relief in recognition of the fact that some disasters are so severe that state and local governments lack the means to respond and recover on their own.

Federal involvement in disaster relief is activated if the President declares a 'major disaster' following a formal request by a state government. The federal government will then agree to supplement state and local relief and recovery efforts. The number of major disaster declarations has been increasing. They have almost doubled in recent decades, from 24 in the 1980s to 46 per year in the 1990s. Studies suggest that by politicising disasters and disaster victims, states and the media have successfully

exerted pressure for major disaster declarations to be made for smaller scale events (Wright 2000, pp. 59, 67–8, 92–3; IFMRC 1994, pp. 181–2).

Many express concern that too much federal support can have negative consequences. Generous disaster subsidies can increase state and local government dependency and reduce the imperative for them to invest in disaster prevention and preparedness. While accepting the benefits of occupying floodplains, the costs of occupying that land are externalised to federal governments and taxpayers. State and local governments are responsible for land use in the United States, and the implementation of development controls is widely held to be the most effective flood-prevention tool. There is a fundamental disconnect if those responsible for implementing development controls are different to those who pay for the consequences of failing to implement them (Larson 2009, p. 10; Wright 2000, pp. 67, 72; Kousky et al. 2011, pp. 30–3; ASFPM 2007, p. 7; NWF 1998, pp. 125, 137–8).

Evidence for the effectiveness of non-structural measures in preventing flood damages was first provided by the Tennessee Valley Authority when it developed a program to implement Gilbert White's concepts on alternative flood control:

> The TVA's 'experimental program' identifying flood prone areas and assisting regulation of appropriate land-use reported its success to Congress in 1959. The program was said to be 'saving lives and property in the area while diminishing the future demands on the nation for flood-relief and flood-control expenditures. (Wright 2000, p. 20)

However, structural measures continued to dominate federal spending, and the costs of flood damages continued to grow. Despite extensive investment by the federal government in structural flood control, flood damage costs doubled between 1958 and 1972, due to people continuing to settle in flood-prone areas (Wright 2000, p. 31).

It was not until 1974 that Congress began to provide adequate support for non-structural measures. This was enabled through the *Water Resources Development Act 1974*, which required non-structural flood control alternatives to be considered by all federal agencies. The Act also required that agencies meet at least 80% of the costs of non-structural measures (Wright 2000, p. 63).

The 1993 floods in the upper Mississippi caused another major shift in disaster relief. Wright reports that there was a 'consensus that rebuilding or restoring to pre-flood conditions was not an acceptable policy position' (p. 78). Early attempts to integrate mitigation into recovery were not wholly successful, due to the speed with which recovery measures need to be implemented following a disaster, and the time required to assess appropriate options – somewhat reminiscent of current Australian problems with implementing 'betterment' (Comrie 2011, p. 211).

During the 1990s, recovery and mitigation increasingly became integrated, and in some disasters became one and the same. Recovery funding took the form of purchase of damaged or destroyed property; rebuilding away from flood hazards; and reducing exposure of rebuilds through measures such as elevation of structures. With the *Hazard Mitigation and Relocation Assistance Act 1993*, mitigation funding increased, and 15% of all federal disaster costs were required to be spent on mitigation. As a consequence, thousands of properties have been elevated, acquired or relocated. In the case of Grafton, Valmeyer, Rhineland and Pattonsburg, whole communities were relocated (Wright 2000, pp. 69, 78–9).

Healy and Malhotra make the point that voters tend to reward disaster relief more than disaster prevention/preparation. Among the reasons for this are that in the former, funds tend to be directed towards community-scale projects, the benefits of which are not

immediately realised. Relief payments, on the other hand, tend to be paid directly to individuals and are of immediate relevance and benefit. They find that 'voters only value relief when those expenditures are individually targeted, but appear not to value prevention under any circumstances' (Healy and Malhotra 2009, pp. 7–8, 24–5).

In Australia, the *Australian Government Disaster Recovery Payment* of $1000 per adult and $400 per child was offered to everyone living in an area affected by the floods ($800 million). It was tax free, could be spent on anything at all and was non-means tested. In the light of Healy and Malhotra's (2009) findings, the wisdom of making direct payments could be questioned, particularly if it reinforces the current funding imbalance between prevention/preparedness and response/recovery.

While Healy and Malhotra (2009) found that community-scale projects were not valued, it seems this is not always the case. A report into FEMA mitigation grants in eight communities found considerable community support for mitigation approaches:

> [T]he federal hazard mitigation grants often led to additional or synergistic activities. Interviewees in all communities thought the FEMA grants were important in reducing community risk, preventing future damage, and increasing a community's capability to mitigate natural hazards. Most interviewees believed the grants permitted their communities to attain mitigation goals that might not otherwise have been reached. Interviewees also believed that the benefits of the mitigation projects went beyond what could actually be quantitatively measured. These included increased community awareness, esprit de corps, and peace of mind. Virtually every interviewee believed that their community was better off as a result of FEMA mitigation project and process grants being completed. (National Institute of Building Sciences 2005)

Australian disaster relief is administered through the Natural Disaster Relief and Recovery Arrangements. The 2010–11 floods cost Australian taxpayers $5.6 billion in Commonwealth money for Queensland alone (representing three-quarters of the total public expense), with additional amounts coming out of state government budgets (Gillard 2011). For a country with a relatively small population, this is a significant cost. The funds are expected to rebuild state infrastructure to pre-existing standards.

In order to fund this enormous recovery bill, the Commonwealth government implemented an additional tax levy on Australian income earners (not applicable to anyone living in a flood-affected area or to low income earners). It also reduced or discontinued spending to numerous Commonwealth government programs. The vast majority of these programs were 'Clean Energy' programs: the Cleaner Car Rebate Scheme, the Green Car Innovation Fund, the Carbon Capture and Storage Flagships program, the Solar Flagships program, the Renewable Energy Bonus Scheme, the Green Start Program, the Solar Homes and Communities Plan, the Global Carbon Capture and Storage Institute. Other programs that were cancelled or reduced included the National Rental Affordability Scheme, the Australian Learning and Teaching Fund, the LPG Vehicle Scheme and a number of regional and local infrastructure programs. It can be concluded from this that Australians, both individually via increased tax and as a nation, have sacrificed much to subsidise the flood relief effort. It is also ironic that many of the programs sacrificed are the ones designed to mitigate climate change, a phenomenon likely to increase our exposure to flooding.

Disaster mitigation is not currently integrated into Australia's disaster relief. The COAG National Strategy for Disaster Resilience lists as a priority outcome:

> Following a disaster, the appropriateness of rebuilding in the same location, or rebuilding to a more resilient standard to reduce future risks, is adequately considered by authorities and individuals. (COAG 2011, p. 12)

Evidence from Australian flood reviews makes it clear that this aspirational objective is far from being realised. Commonwealth involvement in disaster relief is through the Natural Disaster Relief and Recovery Arrangements (NDRRA), which are activated if financial thresholds for disaster costs are exceeded. When this is the case, the Commonwealth government will share disaster costs with state governments. The proportion of assistance depends on the amount of damages. For 2010–11, the Commonwealth's share became 75% when the cost of replacement in 'Category B' (including replacement of essential public assets) reached $155 million. While 'betterment' – or rebuilding to improved standards – is technically allowed by the NDRRA, Comrie reports that, to date, no betterment projects have ever been approved by the Commonwealth (Comrie 2011, pp. 207–11).

Disaster mitigation in Australia is funded separately, through the National Partnership Agreement on Natural Disaster Resilience (NPA). This program was formed in 2009, and combines earlier programs for disaster mitigation works and programs to support emergency management volunteers. The new program provides roughly $27 million per year, covering all hazards and divided between all states and territories (Attorney-General's Department 2012b).

The US sources make it clear that simply rebuilding is unacceptable. Commonwealth involvement in disaster relief needs to be considerably more strategic if it is to reduce future flood losses. Currently, Commonwealth disaster funding is provided when relatively low financial triggers are reached. Funding provisions not only do not require rebuilding to better standards, but make it difficult to do so. The generosity of Commonwealth support does little to foster state and local government responsibility or accountability for irresponsible planning decisions. Indeed, 'victims' are expressly exempt from contributing to recovery costs. This is not likely to increase Australia's resilience to disasters.

In common with the United States, it is the state and local governments that are responsible for land-use decisions in Australia. Thus US views regarding appropriate roles for federal government are worth considering. A report by the US Interagency Floodplain Management Review Committee, *Sharing the Challenge*, recommends that the division of responsibilities for each level of government regarding floodplain management needs to be clearly defined, including a requirement that communities share in the costs of their land-use judgements. It argues that the appropriate role for the federal government and its programs is to provide the support and tools required to carry out effective floodplain management. This needs to be in the form of leadership, technical information, data and advice, setting standards, and providing incentives and penalties. The federal government also has a partnership role in funding floodplain management activities. Cost-sharing of such activities is essential so that state and local governments retain a stake in them (IFMRC 1994, pp. 68, 74–5).

6.3.11 Relocation

An excellent quote on the dangers of hasty rebuilding is found in an American report on voluntary property buyouts entitled *Higher Ground*:

> The wake of a flood is an emotional time and the tendency is to rush in and fix what's been ruined and damaged. But people should think hard first. In our experience, rushing to rebuild is not always the best course of action. It's time to ask if rebuilding in an area prone to flooding is worth it,

> or if it's just reinvesting in disaster. (Charles L Hardt, Tulsa Public Works Director, 1993, quoted in NWF 1998, p. 144)

Relocation is widely supported – even from agencies with a structural focus – and it is a measure used by FEMA through the NFIP and by USACE (Wright 2000, pp. 38, 47–8). A USACE report into coastal protection and restoration recognised the considerable benefits of buyout and relocation in providing improved safety, lower potential flood damages and opportunities for alternative land use (USACE 2008, p. 65).

American relocation strategies are very closely tied to national disaster relief (see section above). Wright reports that relocation strategies began in earnest in 1988 when amendments were made to federal disaster relief and emergency assistance provisions to include funding to purchase damaged or destroyed property.

Funding for relocation was substantially increased following the major 1993 flood in the upper catchment of the Mississippi, which led to the passage of the *Hazard Mitigation and Relocation Assistance Act 1993*. This Act clarified the conditions for purchase, including a requirement for the complete removal of structures and a requirement that land purchased revert permanently to open space uses, such as recreation or wetland management. The Act prohibits any future federal expenditure on disaster relief or rebuilding on land purchased through the program. According to Wright, writing in 2000, the program had bought and removed an estimated 20 000 structures since its inception (Wright 2000, p. 69); NWF 1998).

Other legislation relating to relocation is found in section 555 of the *National Flood Insurance Reform Act 1994*. This requires that communities participating in the NFIP adopt laws requiring that 'substantially damaged' properties (where damage is equal to or greater than the value of the property) be elevated to the 1 in 100 year flood level or removed from the floodplain. This also applies to the cumulative damages of repetitive loss structures (NWF 1998, pp. 53–4; 57).

The *Higher Ground* report stresses the importance of such land acquisition programs being voluntary, due to the fact that many of the most hazardous areas are inhabited by the poorest and most vulnerable sections of society. Often similarly inexpensive land is not available for purchase, and this forms a barrier to such programs. Improvements to property may be similarly unaffordable, which is why the 1994 Act also makes provisions for supplementary mitigation insurance (see NFIP section) (NWF 1998, p. 34; Wright 2000, p. 82).

There are compelling reasons why relocation should be considered following a disaster. A study of relocation in America found that one in ten repetitively flooded properties have received cumulative insurance payments exceeding the value of the property. In one case, a home worth $114 480 had received $806 591 in insurance payouts for 16 flood events over 18 years (NWF 1998).

The financial benefits of implementing relocation programs have also been calculated. Following the 1993 flood in Missouri, a voluntary buyout program was implemented. Major floods recurred in the same region in 1995. According to the Missouri Emergency Management Agency, the buyout program resulted in a 99% drop in federal, state and local disaster assistance costs compared with the earlier event, from US$26.1 million down to US$283 094 (NWF 1998, pp. 60–1).

Relocation is often seen as an expensive option in Australia. However, the American experience suggests that this is not always the case, particularly when avoided flood damages are considered. Freitag et al. (2009) report that the 1993 flood killed 52 people, damaged 1000 levees and destroyed 50 000 homes. It caused an estimated US$20 billion in damage. Following this disaster, more than 300 homes were moved to different sites

and 12 000 homes were bought and demolished, at a cost of $150 million. The vacated land was turned into parks, wildlife habitat and flood-detention areas. Amazingly, a similar-sized '500-year' flood took place in the same area in 2008. While the damage bill of $2 billion was large, it was substantially lower than that of 1993, due to the vacated land that had become available for retaining floodwaters (Freitag et al. 2009, pp. 5–6).

The Australian Department of Transport and Regional Services report studies the reasons why relocation is perceived to be a more expensive option in Australia than America, and concludes that it is primarily due to the accounting method used to assess cost. Whereas America uses replacement cost (thus damages are greater, resulting in greater savings if it is relocated), Australian calculations use 'economic cost'. Economic cost is used in benefit-cost analysis, and it discounts the value of the asset already consumed – that is, Australian calculations use the depreciated value of the property when assessing the benefits of relocating (BTRE 2002, pp. 26–7).

In the United States, the federal government's funding of a national insurance scheme and its liability to pay repeated insurance claims no doubt increase its awareness of the financial consequences of allowing rebuilding to occur in the same location and its willingness to fund relocation. Lack of direct financial consequences for the public purse may be another reason why relocation receives little government support in Australia.

6.3.12 Resilience

Increasing resilience is a key strategy for disaster management in the United States, as it is in Australia. Recommendations relating to resilience are found throughout reports, particularly those relating to levees. A recent National Research Council report, *Disaster Resilience: A National Imperative*, provides some broader societal strategies.

Current approaches to flood management are more sophisticated than in earlier times, when flood control was the objective. Currently, risk management is the focus and in the year following Hurricane Katrina, USACE initiated the National Flood Risk Management Program. It aims to achieve 'shared responsibility' with multiple partners across different levels of government, the private sector and communities. Two of its key aims are reducing the risk of loss of life and reducing long-term economic damages. Activities included in this program suggest a shift towards non-structural approaches and raising awareness of risks. Also included in its list of activities is: 'Assess potential climate change impacts, including impacts to flood and coastal storm infrastructure, and consider adaptation measures' (USACE 2012). Risk-assessment similarly forms the basis of resilience approaches in Australia (COAG 2011, pp. 7–8).

The Hurricane Katrina event highlighted the disproportionate exposure and vulnerability of disadvantaged people to flooding. A total of 1810 people died during the Hurricane Katrina event. Of the confirmed deaths, 75% were over 60 years of age. The poor, the elderly and the disabled were particularly affected, as they were not able to evacuate without assistance (USACE 2009, p. 124; NCLS 2009, p. 12). Flooding discriminates against those who are most disadvantaged in society, as unsuitable, flood-prone land is more affordable (NWF 1998, p. 34). Galloway (2009) reports significant concerns about the impacts of future climate change flooding on vulnerable groups: 'the risk to this group would increase by factors of three to 20' (p. 6). This suggests that any measures to enhance resilience need to pay particular attention to the sections of society that are most vulnerable.

Reports suggest many ways to improve resilience. These include increasing awareness of flood risk, building design, floodproofing, development controls and building codes, emergency evacuation planning and exercise, education, awareness and insurance (NCLS 2009, p. 15; Wright 2000, pp. 40, 48; Larson 2009, p. 10; ILPRC 2006, p. 11; IJC 2000, p. 73).

Improved forecasts and warnings are credited with stabilising flood fatalities despite increased numbers of people living in flood prone areas (Wright 2000, p. 52).

Many reports emphasise the importance of risk-awareness. Risk-awareness is needed not only for the public but also for government officials. Larson attributes unsound development decisions to misunderstanding of risk in the public sector (Larson 2009, p. 10). The NCLS reports that public attitudes to flood risk and fire risk are different, which it attributes to misunderstandings about chance and likelihood. While most people don't hesitate to buy insurance against fire, purchase of flood insurance is resisted, 'even though the chance of flooding is many times more likely than fire' (NCLS 2009, p. 14).

Risk-awareness is particularly important for those living behind levees, as people often become complacent when levees are successful in protecting them from lesser floods. Far from eliminating flood risk, levees can increase risks (NCLS 2009, pp. 14, 16; Larson 2009, p. 11). The lack of public understanding and appreciation of residual risks prior to the Hurricane Katrina event in 2005 have been identified as a key issue that needs to be addressed (National Research Council 2009, p. 6). Many make the point that the risks of living behind levees need to be communicated 'early, often and continually' (NCLS 2009, p. 16). The National Committee on Levee Safety recommends a comprehensive national public awareness/education program to communicate the roles and limitations of levees and what be done to mitigate residual risk (NCLS 2009, pp. 40–6).

Many methods are suggested to help increase awareness of flood risk. Awareness and outreach is one of these and needs to include formal and periodic notification to owners, tenants and lenders about potential risks behind levees (ILPRC 2006, pp. 49–52, 56). Mandatory insurance for those living behind levees is also recommended, partly to serve as a reminder of exposure to residual risk (Galloway et al. 2006). FEMA has reported preliminary success helping communities and individuals identify and manage flood risks, and raising the awareness of potential flooding and mitigation opportunities through its Risk MAP program (FEMA 2012).

Many recommendations relate to mapping of flood risk to enhance awareness. In particular, areas behind levees need to be marked as flood hazard areas on maps (ASFPM 2007, p. 9; ILPRC 2006, p. 22). The identification of the 1 in 500 year floodplain on flood maps is also important to enhance flood risk awareness (IJC 2000, p. 73).

Some reviews have drawn attention to the language used. For example, the term 'flood protection structures' gives a false sense of security, and could be replaced with 'flood risk-reduction structures' (ILPRC 2006, pp. 22–4).

The USACE has made substantial contributions to floodproofing techniques, and has produced both regulations and guidelines. The United States also has a national model-building code that was introduced in 2000 (Wright 2000, pp. 48, 91). The recent review of the NFIP found that the cost of improved building construction was modest if it was incorporated into the original building design.

Improving development decisions and building standards are of prime importance to achieve resilience. In the United States, federal government has been involved strongly in the development of land-use regulations as a consequence of its implementation of the NFIP. This is in spite of the fact that land use is a state and local government responsibility. The federal government's role in facilitating the use of development planning began in 1968 with the publication of draft statutes and local ordinances for land-use regulation in flood hazard areas. This was followed in 1978 by a guidelines document (Wright 2000, p. 43). While this has improved planning decisions significantly, a lack of local responsibility and accountability for poor planning decisions is a key issue.

A number of reports find that sharing the costs and consequences with those responsible for poor planning will help to ensure that better decisions are made (Larson 2009, p. 12; IFMRC 1994; Galloway et al. 2007, pp. 9, 23; IJC 2000, p. 69).

In order to foster resilience, it is very important to provide adequate support to local planners, and assistance needs to be ongoing in recognition of staff turnover (Wright 2000)(p.49). Some also stress the need for research into social dimensions and knowledge about what changes human behaviour (Larson 2009; IJC 2000, p. 69).

The recent National Research Council report into disaster resilience supports other report findings relating to improving risk communication and the adoption of sound land-use planning, and building codes and standards. It recommends broad-based commitment to a risk-management strategy using a combination of structural and non-structural approaches.

The report suggests a number of tools that can be used to assess resilience, such as the development of indicators as a consistent basis for measuring resilience, and use of a national resilience scorecard. A national repository for all-hazard event and loss data is also suggested to improve understanding about geographic and historic patterns of disaster loss. This would serve to motivate and would also help prioritisation.

The report also advises 'infusing the principles of resilience into all the routine functions of the government at all levels', and ensuring that a long-term view of resilience is taken, as short-term measures can reduce resilience. A national vision or organising principle is suggested as a way of achieving this but more practical measures are also presented, such as linking public and private infrastructure performance to resilience goals and resilience policy review of programs and policies.

The importance of a 'bottom-up' approach is stressed as local conditions, societal characteristics and hazards vary. This could be achieved through the creation and maintenance of local and regional community resilience coalitions (National Research Council 2012).

6.3.13 Floodplain restoration and ecosystem approaches to flood management

The US approach to floodplain management is evolving from one that is highly engineered to an approach that also integrates floodplain restoration. A report on the 2011 floods in the Mississippi River compares flood management in 1927 with current practices. In 1861, the United States settled on a 'levees only policy', excluding other forms of flood control. However, in 1927 this backfired disastrously when the volume of floodwater caused a series of levees to fail in a domino effect, causing widespread damage and fatalities, causing a reassessment of flood-control measures (Mississippi River Commission 2011).

The Mississippi is still managed using 'a variety of intensely managed engineering techniques', including an extensive levee system, channel regulation, reservoirs and pumping stations (Mississippi River Commission 2011). However, the 1927 floods reinforced the limitations of engineering methods. Managers now incorporate parts of the natural floodplain into their flood management options, including 366 000 acres (148 000 ha) of designated floodway and 1.652 million acres (668 540 ha) of backwater. When activated, these divert excess flows and relieve pressure on levees. During the 2011 floods, even though flows were similar to those experienced during 1927, flood extent was reduced by 62% (Mississippi River Commission 2011). By way of caveat, the use of floodways during floods requires human intervention and the decision to use them can be contentious and reliant on the judgement of a single individual. A gripping account of the decision to open the Morganza spillway in May 2011 shows just how easy it could be for the wrong decision to be made (Camillo 2012, pp. 259–64).

In recent years, flood mitigation and floodplain restoration have increasingly become integrated, with the introduction of various legislative and regulatory provisions, the creation of a long-standing inter-agency floodplain management taskforce, multi-objective planning, integrated wetland management, and the publication of tools and guides. This approach has also been supported by influential organisations such as the Association of State Floodplain Managers (ASFPM). Increasing public concern for environmental protection has made this an attractive approach (Wright 2000, pp. 43, 45–6, 52, 61–5, 73, 84). However, according to the ASFPM, effective state and local floodplain management requires strong financial, legal and operational foundations, and is very vulnerable to budget cuts and restructures. The advantages of combining floodplain restoration with flood management are demonstrated in Section 6.3.14.

Some specific issues relating to landscape-scale management have received recent attention. One of these is the degradation of saltwater marshes (Aldhous & Jabr 2011; Solomon 2011). These marshes have a role to play in providing natural protection from storm surge and modelling to assess potential of wetlands in protecting New Orleans from storm surge has recently been carried out by USACE, though modelling techniques still need to be refined (National Research Council 2009, p. 19).

Case study:
Integrated catchment approaches in Queensland

Managing the landscape to best mitigate flooding is hard to do at the local level, as measures implemented locally can worsen flooding elsewhere. One solution is the implementation of catchment approaches at the state government level.

In Queensland, Australia, excess fertiliser use has been blamed for nutrient pollution, leading to degradation of the Great Barrier Reef and sea grass beds. With larger floods and longer droughts, erosion and nutrient run-off are likely to increase as a result of climate change. To address this, an innovative $50 million reef protection package, 'ReefWise Farming', is being implemented by the Queensland government to improve farm management. The plan aims to simultaneously reduce erosion and nutrient run-off while increasing farm profitability. It uses research, extension and regulatory measures. The program targets are to reduce the discharge of pesticides and nutrients flowing to the reef (50% by the end of 2013) and to cut sediment flowing to the reef (20% by 2020). This is seen as vital for improving the resilience of the reef which is likely to suffer the additional pressures of ocean acidification and warming as a result of climate change (Queensland Government 2012b).

Protection of wetlands is also incorporated into the package of measures, with State Planning Policy 4/11: Protecting Wetlands of High Ecological Significance in Great Barrier Reef Catchments coming into effect in November 2011. This planning instrument is designed to regulate earthworks by maintaining a buffer of 50–200 m around wetlands in the Great Barrier Reef catchments. Protection does not extend to river channels, however, and the connectivity between rivers and wetlands is not addressed (Queensland Government 2011).

The confinement of sediment between levees has prevented natural sediment deposition of coastal marshes to the south and east of New Orleans, causing the marshes to degrade. This prevents them from providing the city with natural protection against storm surge. According to Solomon, 2300 miles^2 (3700 km^2) of coastline has been lost. By opening up floodways, sediment can be deposited to create new marsh, bringing with it both flood protection and ecological benefits. There are currently plans to develop two additional diversions into other degraded marshes south of New Orleans.

Wetlands also have a role to play in improving water quality. They capture floodwaters, filter nutrients and release water gradually. By contrast, highly regulated channels convey floodwaters (and the nutrients they carry) into the ocean as quickly as possible. Excessive nutrient run-off has caused algal blooms and an oxygen-depleted 'dead zone' in the Gulf of Mexico of 24 000 km^2, to the detriment of fisheries and coastal ecosystems. Flood diversions that increase the number of floodwater outlets along the coastline are believed to have increased the size of the dead zone, suggesting that reduced fertiliser usage as well as wetland restoration are needed (Aldous & Jabr 2011; Solomon 2011).

6.3.14 Costs, benefits and co-benefits

Considerable research has been conducted in the United States into the costs and benefits of different approaches to flood management. The studies point to where in the PPRR process it is most economical to intervene, and to which measures are the cheapest and most effective. There has also been research into the economic value of co-benefits, the additional benefits associated with some types of flood control measures.

A study analysing the cost-benefit of mitigation grants conducted by the National Institute of Building Sciences found that every dollar spent on flood mitigation saved society an average of $4.10 in avoided post-disaster relief and increased taxation, with similar results for prevention of other hazards (National Institute of Building Sciences 2005, p. 149). Another study conducted by economists Healy and Malhotra (2009) suggests a dollar spent on disaster preparedness[14] is worth about $15 in terms of the future damage it mitigates. Evidently, the adage 'prevention is better than cure' is true for disaster management. The cost-effectiveness of mitigation expenditure is similarly recognised by the Australian government, although implementation of mitigation measures has proved hard to achieve (BTRE 2002; COAG 2011).

Significant research has been conducted in the United States into the relative merits of structural and non-structural approaches. In 1992, the US Federal Interagency Floodplain Management Task Force carried out an assessment of national floodplain management. Wright (2000, p. 72) lists 12 of its key findings, among them 'the application of additional structural measures is viewed as limited because of economic and environmental considerations'. Another study by Kousky et al. (2011) notes that structural forms of flood control are expensive both to construct and maintain and generally have external costs for other communities. There seems to be less willingness to fund structural measures than in the past; the US Army Corps of Engineers 'has a huge backlog of flood control projects and a smaller budget than in decades past, making new federally funded structural flood control projects much less likely' (p. 34).

By contrast, Kousky et al. (2011) point to numerous benefits of 'green infrastructure' approaches, such as wetlands, land-use change (including relocation and improved land

[14] Both prevention and preparedness expenditures are included in their 'preparedness' category, while 'relief' is primarily recovery measures and does not include response. The study is not confined to flood disasters and it does not distinguish between structural and non-structural measures.

management practices) and permeable surfaces such as bioswales, detention basins and rain gardens. They report that a catchment with just 5–10% of its area covered in wetland can reduce peak flows by 50% compared with the case of no wetlands (pp. 36–7). Green infrastructure not only reduces stormwater peaks but also reduces water pollution. This has additional economic benefits:

- A study on fish abundance in the Great Lakes suggests that improved land management (e.g. restoring wetland buffers, addressing non-point sources of agricultural pollution and soil loss) would improve fish abundance by 30–75%, having an estimated value of between $1.1 and $5.8 billion dollars.
- Studies on the economic value of beach water quality of the Great Lakes suggest an improved value of $4.5-$5.5 billion due to a 20% reduction in beach closures.
- Correlations have been observed between improvements in water quality, proximity of wetlands and local property values. Studies further suggest a willingness to pay increased local taxes to achieve improved water clarity (dependant on a range of factors such as proximity to water and income)(Kousky, Olmstead et al. 2011)(p.50-55).

A report into reducing flood impacts in the Red River Basin found wetland storage to be economically and environmentally beneficial for reducing flood peaks. This was particularly effective for the mitigation of frequent, smaller floods. For large floods, the report found this approach would need to be used in conjunction with other methods (IJC 2000, pp. 24–5).

Kousky et al. (2011) calculated the benefits of avoided flood damage using the Hazus tool (a GIS model developed for FEMA to help local governments and emergency planners to estimate disaster losses). In their study of Wisconsin's Lower Fox River Basin, they found annual avoided flood costs from the present to 2025 would be US$2.36 million. The study also weighed up the costs of reserving vulnerable floodplain land that had been designated for future development, based on current property prices and the costs of buying easements (i.e. land remains privately owned but future development and farming practices are restricted). Purchase of easements was found to be approximately 60% of the property value. Considering both property size and depth of flooding (the acre-foot measure), as well as property value, they were also able to identify which properties it would be most cost-effective to target. They found that protecting 86% of the land from development would yield similar flood protection benefits as 100% protection, while costs of achieving this became significantly lower (annual $1.15 million, as opposed to annual $5.10 million buying 100% of the land or $3.06 million buying 100% of easements) (pp. 38–42).

The Hazus tool can be very useful in cost-benefit analysis. However, some caution should be taken in relying on conventional cost-benefit alone. It can omit important indirect benefits and indirect costs. Another tool to determine the best option to address a flood risk was developed by Freitag et al. (2009). Their decision-making framework can be used by both individuals and local governments to determine the best option to suit their specific situation. The framework is based around six questions (pp. 8–14, 159–87). In one example, the cost of structural flood protection is compared with the cost of relocation:

> Soldier's Grove Wisconsin was a poor community that was in economic decline due to repeated flooding. Congress approved structural works (a dam and a levee).
>
> The levee would cost $3.5 million to protect about $1 million worth of property. Each year for the next 100 years, the village would have to raise funds equal to twice its 1975 property tax levy to pay for maintenance of

> the flood-control structure. Community leaders suggested that the federal government spend the same $3.5 million to help the community evacuate its floodplain and rebuild the business district on higher ground.
>
> The village was granted $900 000 for relocation. The relocation resulted in numerous other benefits, including energy efficient housing, economic renewal, recreational facilities at the old town site and improved water quality and supply. The flood mitigation benefits were realised when the biggest flood in history hit in 2007, overtopping levees and causing high waters for 10 days. This flood caused no damage to the new town and only minimal damage to riverside facilities. (pp. 47–51)

In another example, a farming community chose not to repair a levee damaged by floods. The agricultural land protected by the levee was unproductive and levee district taxes rose each time the levee breached (on average every four years). To restore flood damaged land and repair the levee would have cost the community $4 million. Landowners decided to not to accept offers to repair the levee but instead sold easements so that the land could be managed as wetland reserve. Many later sold their land outright, with project costs for the wetland totalling $2 million. Dissolving the levee district ended up being a cheaper option financially than restoring it. The project also provided habitat for wildlife and flood mitigation for the community and downstream users (Freitag et al. 2009, pp. 14–17).

Protecting water catchments can have significant benefits, not only for flood protection but also for water quality. When development in the Catskill/Delaware watershed threatened New York's water quality, the city found it more economical to preserve the wetlands and the natural character of the basin than to invest in water-filtration systems. The cost of acquiring or contracting land was US$131 million (noting that at this figure represents the costs of a 15-year program one-third the way through). By contrast, the filtration plants would have cost $7 billion in capital, $400 million in annual maintenance costs and would have been vulnerable to malfunction and terrorist attack. The protection of the natural water system has additional benefits for Catskill residents as well as New Yorkers, including flood protection, water quality and market development for previously unrecognised tourism opportunities (the area being close to New York) (Freitag et al. 2009, pp. 69–72).

Both Freitag et al. (2009, pp. 190–1) and Kousky et al. (2011, pp. 1–2, 63) note the applicability of non-structural ecosystem approaches for adaptation to climate change. They are cost-effective and result in communities and landscapes that are more resilient to change. Others writers also make the point that reducing vulnerability to climate extremes is a 'no regrets' measure that will benefit disaster resilience, regardless of future climate uncertainties (Pittock 2009; Etkin et al. 2012, pp. 203, 594).

While many benefits of healthy ecosystems are not measurable in economic terms, US agencies have attempted to quantify the economic values of some co-benefits such as wildlife watching. In 2003, the US Fish and Wildlife Service published a report that found wildlife watching was one of the most popular forms of recreation in the country. In 2001, over 66 million Americans spent $38.4 billion on wildlife watching activities (this figure excludes hunting and fishing). Expense categories included trips, equipment and 'other' (which could include membership and journals). 'Total industry output' included 1 027 833 jobs and $27.8 billion in salaries (Caudill 2003).

Australian agencies have not quantified the value of the industry for Australia, but a report produced by the Cooperative Research Centre for Sustainable Tourism found that birdwatching 'is one of the most rapidly growing pastimes in the Western world', accounting for significant numbers of international tourists. It found that birdwatchers tend to be both well educated and affluent (Jones & Buckley 2001). Clearly, the

protection of wildlife habitat and its connectivity has an economic value for tourism as well as value for flood protection or inherent value. The tourism benefits of protected wetlands are well recognised by some local governments such as Leeton Shire Council, which organises an annual Australian Birdfair (Leeton Shire Council 2012).

American research clearly shows that it is more economical to invest in proactive approaches to flood control and that, while structural approaches are appropriate in some cases, the most cost-effective measures are non-structural. Unlike structural measures, they tend to be cheaper, longer-lasting, and have few external costs and considerable co-benefits.

6.4 Assessment of the applicability of US approaches to Australia

In many ways, Australia is behind the United States. The 1:500 year standard is now widely recommended for both urban levee height and for broader application of risk reduction measures in floodplains. There is growing support for ecosystem approaches in the United States and the application of advanced cost benefit analysis is increasing evidence about the advantages of system based, non-structural approaches to flood management. The United States is also much further advanced in its strategic approach to disaster recovery, with a legislated requirement that 15% of all disaster recovery funding be spent on mitigation. This includes significant funding for voluntary relocation.

However, it is sometimes an advantage to be left behind, and Australia has the opportunity to learn from the failures of the United States as well as its successes. The United States has progressed much further on the track of levee construction, and levee-focused reviews describe a litany of costs, uncertainties and damages related to the use of this approach. Many of these are rarely conceived of by levee proponents in Australia, but are now obvious in the United States. If levees are to be used at all, they must be used well – and, as in the Netherlands, the consequences of levee failure must always be in sight and planned for.

Australia can also learn from America's massive federal expenditure on disaster relief, which has reduced local accountability and responsibility for planning decisions. In the United States, disaster relief and mitigation have become increasingly integrated, with federal funding often being conditional on the adoption of appropriate land use controls. Recent Australian government expenditure on flood recovery lacks focus and the massive proportion of flood recovery funded by the Commonwealth could act as a disincentive to the responsible implementation of land use regulation and building codes by state and local governments.

The US federal government's National Flood Insurance Program has both stimulated the use of development planning and created perverse incentives that encourage floodplain development. Options for flood insurance in Australia have recently been examined. While Australia has chosen not to implement a government-backed flood insurance scheme, elements of the US insurance program, such as the Supplementary Mitigation Insurance Program, could make a contribution to Australia's resilience, resulting in lower long term liability for Australian insurers.

Table 6.1: Comparison of international approaches to flood

Measures and approaches	China	Netherlands	USA
Traditional approaches to flooding	Structural approaches: flood levees a primary measure with a long history. Use of dams for flood mitigation significant from the 1950s.	Structural approaches, including dykes, canals and river regulation to prevent inundation and ensure fast drainage. Long history of management and local responsibility through Water Boards.	Levee-only policy 1866–1927, and continued to be a key approach thereafter. Development planning, flood insurance and disaster relief have evolved since the 1960s.
Key issues influencing current approaches	• Increasing flood frequency • Increasing flood depth • Increasing variability and extremes anticipated with climate change • Large-scale economic losses and casualties • Reduced water quality • Degraded natural resources • Loss of landscape capacity to store floodwater	A series of 'near-miss' floods during the 1990s prompted a rethink about structural approaches to flood control. Concerns include: • Additional climate change threats • Protection of key societal values and prosperity • Environmental impacts of structural approaches • Managing for drought as well as flood • Population increase Clear national vision with flexible temporal and local implementation.	Hurricane Katrina (2005) a catalyst for reassessment of approaches. Escalating costs of flood damage a key issue. Future flood risks expected to magnify due to climate change, population increase, urbanisation and future levee construction.
Structural			
Flood levees, dykes and polders	Continues to be important but no longer used exclusively. Drawbacks recognised include: • Higher flood levels • Siltation of river channels, wetlands and floodplains, reducing flood storage capacity • Loss of wetland connectivity • High maintenance costs • High consequences of levee failure	Dykes continue to be key to flood defence but reliance on this measure is reducing due to: • Higher dykes: higher pumping costs • Higher consequences if dykes fail The way they are used is also changing: Partially lowered polders allow water to flow through when water levels are high. Artificial mounds enable continued habitation. Levee setback, lowering of water channels,	Multiple issues with levees identified in recent reviews, including: • Levees enable development of flood prone land; large consequences of levee failure. • False sense of security reduces resilience. • Level of protection declines with time due to structural deterioration and changing catchment conditions. • High cost of construction, regulation, maintenance and repair. • High environmental costs. • Transfer of flooding to others; worse flooding

Measures and approaches	China	Netherlands	USA
	Improved management has successfully restored seasonal linkages between rivers and lakes in some areas. Other strategies include dredging and dyke management, reinforcement of key levees.	groynes and floodplains to increase floodable area and channel capacity.	overall. Key recommendations include: • Needs a catchment approach. • Improvements can be made (e.g. spillways, levee setback, rigorous administration). • Better awareness and contingency planning needed for those behind levees.
Storm surge barriers	No information	A vital defence in a country 50% below sea level. 'Closable open' gates enable the maintenance of ecological function when water levels are low.	Used in some areas.
Dams	Structural safety of dams questioned if flows increase due to climate change. More flexible operational management to balance supply and flood mitigation.	Key concern is that development does not compromise future ability to increase water storage capacity.	Issues with community safety, aging infrastructure, capacity of dams to cope with larger flooding. Flood mitigation and supply functions: conflict between these is expected to grow with climate extremes, requiring improved operating procedures, forecasting and decision support systems.
Non-structural			
Land management and development control	Compatible land and wetland use are key strategies. Legislated requirements governing cultivation practices, land zoning, impact assessment of development.	Water is a key determining factor in spatial planning, application of a Water Test. Planning has a long-term view (200 years) to ensure flexibility and adaptability to future conditions. Use of building regulations, compatible materials and design. Local plans designate land use. Some innovative approaches to update local land-use plans.	United States pioneered the use of development controls in 1950s and 1960s. Federal government publishes draft statutes, local ordinances and guidelines for land use regulation in flood hazard areas. Land management a state/local responsibility. Has been recognised as key element in enabling resilience.
Flood Protection Standards	Level of protection based on population size and area of farmland. Varies from 1:10–1:20 year event to 1:50–1:100 year event.	Long-term risk assessment. Consequence of dyke breach is so high that protection standards vary from 1:1250 year	1:100 actuarial insurance standard used to implement the national flood insurance program. Has been applied to levees protecting development on flood prone land. 1:500 proposed as more

Measures and approaches	China	Netherlands	USA
		(riparian) to 1:10 000 (highly developed northern coastal area). Acceptable level of disaster-related deaths based on pragmatic determination of optimal safety standards.	suitable for urban areas due to higher consequence, evacuation difficulty, alignment with other safety standards. Many older USACE levees to higher standard. Significant questioning of suitability of 1:100 due to mapping inaccuracies, catchment changes, future development and climate change Risk-management approach. Cost-benefit analyses emphasise economic considerations and omit or underestimate indirect or non-economic costs and benefits.
Building design	No information	Innovative flood-compatible design and materials encouraged.	National model building code. USACE has produced regulations and guidelines. Most cost-effective if incorporated into original design.
Vegetating upper catchments	Erosion a key issue. Revegetation supported by national policies and legislation. Also includes a logging ban. Enforcement issues.	NL is the 'lower catchment' of continental Europe. Revegetation is carried out as part of its multifunction approach to river management.	No information on upper vs lower catchment strategies for vegetation. Maintenance of levees forbids vegetation other than turf. Levee setback can allow revegetation. Vacated land from relocation is often revegetated.
Room for River	Yes – through relocation, reversal of land reclamation (polder removal) and restoring wetland connectivity and ecological function. Successful implementation found to have the following program elements: communication and outreach, alternative livelihoods, adaptability to local needs, transition subsidies, alignment with government policy,	Country that originated this concept. Achieved through flood compatible land use, levee set back, relocation, wetland restoration, re-meandering, allowing flow-through of some poldered areas, creating water-retention areas, lowering floodplains. Storing floodwaters longer has benefits for buffering climate change water shortages.	Floodways are used, though they are highly regulated and require human judgement and intervention. Relocation has made vacated land available for water storage. Wetland restoration has had multiple benefits for water security and water quality, tourism and the environment as well as for flood mitigation. Highly cost effective.

Measures and approaches	China	Netherlands	USA
	demonstrations and pilots. Has had successful social, economic and environmental outcomes.		FEMA runs graduate courses in floodplain management that emphasise an ecosystems approach.
Integrated River Basin Management; cross-sector approaches	IRBM is supported by China's Water Law. Decentralisation has made land management measures hard to enforce. IRBM addresses multiple interests to help ensure cooperation.	Optimal outcomes for all stakeholders is a key concern and projects aim for multiple benefits across sectors. Methods of involving communities are highly successful in reducing conflict and lengthy litigation processes.	Championed by influential Association of State Floodplain Managers, by an inter-agency taskforce. Tools and guides published. Evidence of cost-effectiveness of multiple benefits resulting from cross-sector planning. Vulnerable to budget cuts and restructures.
Payment for Ecological Services	Yes – in the form of government subsidies.	Payment provided for land management, use of land to store water during floods and drop in land value.	No information.
Beach nourishment	No information	Used to combat beach erosion.	Highly regulated Mississippi River and Tributaries has prevented natural sediment delivery to coastal marshes, reducing natural flood protection. Plans underway to open floodways to transport sediment, restore marshes and create new ones.
Relocation	Large-scale and involuntary. Compensation arrangements often unsatisfactory. Some positive examples (see wetland restoration).	Relocation sometimes voluntary, sometimes involuntary, according to national interest. Land exchange a cost effective method of acquiring property but requires long-term strategy.	Integrated into disaster recovery, 15% federal disaster costs are required to be spent on mitigation (purchase of damaged property, rebuild elsewhere or to more resilient standards). Relocation has resulted in significant avoided damages.
Legislation	Addressing development planning, water quality, land use and land management	EU Directive requires a catchment based approach and flood risk-management plan.	Policies and legislation relating to insurance, relocation, disaster relief and recovery, water resources development.
Forecasts, warning systems, information systems, evacuation	Increasing effort in preparation for floods through these means.	Important, but given less emphasis than preventative approaches. Evacuation planning is an important contingency measure.	Has substantially reduced fatalities and is a key 'resilience' strategy.
Public education	Used to assist compliance with legal measures.	Community awareness of flood risk to achieve political support for measures rather than community resilience.	Public education stresses risk-awareness to support the resilience approach, especially for those living behind levees.

Measures and approaches	China	Netherlands	USA
Resilience	Flood Control Law specifies responsibilities of government and citizens in flood control.	Government assumes full responsibility within dyked areas but involves community in prevention/mitigation. Outside dyked areas, costs of protection and flood damage are borne by residents, with government only providing advice, warning, evacuation and imposing building requirements.	An emphasis on community resilience, stressing risk awareness, development controls, building codes, warnings, emergency planning and insurance. Infrastructure resilience requires a long term view. Tools proposed: national resilience scorecard, all hazard event and loss data collection for motivation and prioritisation.
Insurance	Compensation laws and flood insurance are 'embryonic'.	Insurance is unavailable. Government compensates damages within dyked areas.	Provided through a national government program. Participation by communities is 'voluntary', but high financial penalties for non-participation. Conditions for participation include adoption of development controls. However, perverse incentives have encouraged development of flood prone areas behind new levees and lower standards of levee building. Recent developments include: repetitively or substantially damaged properties must be rebuilt to better standards or removed from the floodplain; supplementary insurance enables rebuild to improved standards.

7 EMERGING ISSUES

The overall conclusions of this report are provided in the executive summary.

This review has revealed that countries overseas are addressing climate change adaptation to flooding in many different ways, some of which are little known or used in Australia. The potential application of these approaches needs to be explored. Some of these have a social focus. In the Netherlands, reviews have been grounded in a vision of a country 'safe against flooding, while still remaining an attractive place to live, to reside and work, for recreation and investment'. This desire to link into societal values was echoed in interviews. Similarly, need for greater understanding of risk tolerability was an issue raised in both interviews and overseas. Many issues relating to flooding are also highly dependent on education and awareness, and more success in these areas would be of great value for achieving community resilience.

An ecosystems approach to flood management was a common strategy overseas that was used specifically to address climate change threats. The benefits of this approach were numerous, being both flexible and having multiple benefits across sectors. This approach operates best when planned and implemented on a catchment basis. Similarly, other elements impacting on flooding, such as land use and development planning, and location of structural methods of flood control, are better planned and implemented on a catchment level basis to take account of cumulative impacts. However, not all current administrative systems support a catchment approach. Further research into how best to apply a catchment approach to flood management and implementation is needed.

Some technical issues would benefit from further research. For example, a hydrological study in China suggests that some narrow catchments are particularly susceptible to increased flows. There is a water discharge threshold above which water backs up and floods. Identification of potential flash flood areas and their characteristics would be of great value in identifying future risks, given that climate change is likely to increase flash flooding. Flash floods are also some of the most dangerous, as warning time is short.

Finally, some significant institutional and management issues arose. One of the most significant related to funding of disaster relief and difficulties funding rebuilds to a more resilient standard. An approach that 'reinvests in disaster' does little for Australia's capacity to deal with future threats and needs to be addressed.

Noting that some of the following areas are currently being addressed in the revision by Engineers Australia of the Australian Rainfall and Runoff guidelines, the interviewees and project team identified these areas as requiring future research:

- a quantification of the cost effectiveness of betterment and improved procedures to facilitate it
- an assessment of areas in Australia that would most benefit from a catchment-scale ecosystems approach
- an exploration of existing and potential mechanisms to facilitate ecosystem approaches on a catchment scale
- investigation into PES schemes and how they might work in Australia, including, which beneficiaries would pay, how much and by what means
- research into the identification of flash flood areas and improving understanding of them
- application of commercial techniques to flood-risk education
- research into risk tolerability

- research that quantifies the effects of vegetation on flood behaviour to provide a scientific basis for activity
- research into the values that adaptation measures should be seeking to protect
- research into how the current system for disaster relief could be reformed to be better targeted and more cost-effective
- research into statutory or institutional barriers that prevent many of the reforms identified in the reviews to be undertaken (for example, that planning and implementation of flood prevention measures be undertaken at catchment scale).
- quantification of the impacts of natural variability on flood risk, as well as the impacts of anthropogenic climate change, so that future projections can be put into context. This needs to include robust uncertainty quantification.

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APPENDIX 1: TOPIC GUIDE FOR INTERVIEWS

Record:

- Date
- Interviewer
- Interviewee name and contact details
- Interviewee code (e.g. #FPM, #EM, #INS, #LGA)

A. Introduction to the interview process

- Thank interviewee for their time.
- Confirm that they have received the project information sheet.
- Repeat that this research is examining responses to the 2010–11 floods in eastern Australia and the applicability of inquiry outcomes to climate change adaptation.
- Note that we would like to spend between an hour and an hour and a half asking questions in a semi-structured format and that we want to record the conversation.
- Explain confidentiality and determine whether or not they agree to have comments attributed to them/their position; that we would seek to contact them to verify accuracy should we wish to attribute a quote to them; and that they may withdraw at any time.
- Explain the purposes of recording the interview and verify if this is acceptable.
- Ask if they have any questions about the research.
- Ask them to sign the consent form.
- The following are questions designed to elicit open-ended responses which will then be followed up with specific questions that are not on this list.

B. Introductory questions, to establish rapport, expertise and interests.

1. I understand that you have worked on [emergency management/floodplain management/insurance industry/local government] for some time? In what capacities?
2. How many years have you worked on [emergency management/floodplain management/land use planning/insurance industry/local government]?

C. Questions on flood inquiries

3. Which of the recent flood inquiries are you familiar with?
   - Brisbane City Council's Flood Response Review Board report (May 2011)
   - Queensland Floods Commission of Inquiry (interim report August 2011, final report February 2012)
   - Victorian Review of the 2010–11 Flood Warnings and Response (interim report June 2011, final report December 2011), and
   - Parliament of Victoria's Environment and Natural Resources Committee Inquiry into Flood Mitigation Infrastructure in Victoria (report by May 2012).
4. What are your views on the outcomes of flood inquiries, above and beyond that which is evident in the written reviews, including:
   - which key inquiry findings and lessons need to be reinforced and why
   - whether any important lessons or outcomes were not covered by the inquiries?

D. Questions on efficacy of different measures for climate change adaptation and priorities

5. Do you have any opinions on how Australia should to adapt to a climate change scenario that predicts floods of changing frequency or magnitude?
   - the type of measures most likely to assist adaptation to less predictable flood events
   - the type of measures or approaches to avoid
   - any perceptions regarding institutions, emergency policies or organisational structures that could help Australia to manage flood events that are less predictable

- resourcing mechanisms suitable for less predictable flood events (for both prevention/ preparedness and response/recovery phases)
- barriers and opportunities for communities wishing to reduce their risk and vulnerability to less predictable flood events

Can you suggest any case study opportunities for points you have made?

E. Questions on communication of results to user groups

6. What do you think would be the most effective methods of communicating lessons for climate change adaptation and limits to adaptation in your industry [emergency management/land use planning/floodplain management/insurance industry/local government]?

F. Conclusion

8. Is there anything else you would like to tell us?
    - Outline plans to complete this research in late 2012 for project report and academic publication.
    - Offer to forward a copy of the final research.
    - Thank them for their time and help.

Follow up:

- Within a few hours of the interview, make notes on the interview in terms of key points made by the interviewee, new ideas, and the interviewer's impressions.
- Within a few days, send a follow up email thanking the interviewee for their time and repeating the proposed 2012 publication date.
- Later, transcribe the interview for analysis.
- In late 2012, provide the interviewee with a copy of the final publication.

APPENDIX 2: INTERNATIONAL ADVISERS AND END-USERS COMMITTEE

Individual involved	Institution	Nature of contribution
International advisers		
1. Prof. Guangchun Lei	Beijing Forestry University	Adaptive flood management in China
2. Prof. Toine Smits	Radboud University Nijmegen	Adaptive flood management in the Netherlands
3. Prof. (Brig, Gen, ret.) Gerry Galloway	University of Maryland	Adaptive flood management in the USA
End-users' advisory committee:		
1. Andrew Gissing	Victoria State Emergency Service	Emergency management
2. Neil McBeath	Department of Primary Industry, Victoria	Floodplain management
3. John Schauble	Office of the Emergency Services Commissioner, Victoria	Emergency management
4. Ian Rutherfurd	Department of Sustainability and Environment, Victoria	Water, floodplain and environmental management
5. Dorean Erhart	Local Government Association of Queensland	Local government expertise
6. Graeme Milligan	Queensland Reconstruction Authority	Floodplain planning and infrastructure
7. Clive Cook	Queensland Department of Environment and Resource Management	Water, floodplain and environmental management
8. Karl Sullivan	Insurance industry	Risk management and insurance
9. Samantha Capon	Griffith University	Adaptation, water and floodplain management

APPENDIX 3: EXPLANATORY NOTES TO TABLE OF CLIMATE CHANGE ADAPTATION MEASURES FOR FLOODING

The project: Following the 2010-11 floods, several flood reviews were undertaken by state governments and other agencies. A project funded by NCCARF examined four of these reviews to determine if they offered lessons for climate change adaptation. To gain further insight, Australian flood professionals were interviewed and approaches to flooding in China, USA and the Netherlands were investigated (Wenger et al., *forthcoming*). This table summarises findings of the project, with the aim of assisting decision makers to assess the most suitable adaptive measure for their situation. The standard emergency management framework is used to divide measures into prevention/mitigation, preparation, response and recovery (PPRR), offering interventions at different phases of the emergency management cycle.

Changing flood characteristics

Effects of anthropogenic climate change are superimposed on natural variation which can play out over many decades. Warmer sea surface temperatures are expected to increase water evaporation and warmer air is able to hold more water vapour, resulting in more intense rainfall. Flood characteristics that may change include:

- geographic location
- frequency (of both large and small events)
- timing (seasonal)
- magnitude (e.g. volume, depth, area inundated, precipitation intensity, rate of rise, velocity)
- Flood duration

Some variables have a greater effect on flood risk than others. For example, seasonal changes may be relevant to the agricultural sector and the timing of emergency planning but may not to alter risks more generally. Characteristics such as flood frequency, magnitude and duration are also increased by land development, which is expected to continue in coming decades.

Australian flood reviews studied for this project focused on past events and did not assess the adequacy of existing strategies to address future risks. The relevance of review recommendations to climate change therefore had to be assessed. This was done by looking at possible changes to flood characteristics and the effect proposed measures would have on them.

Which measures are adaptive

Hallegatte's strategies, summarised below, are used to help assess the adaptive potential of proposed measures (Hallegatte, 2009). These strategies can help address changing flood patterns regardless of whether this is due to anthropogenic climate change or long term natural variability. Being low cost and flexible, they do not rely on information certainty or accurate local scale modelling.

- **No-regrets strategies:** beneficial even without additional climate change risks
- **Flexible:** for example, measures that are easily reversible, or modified

- **Low cost:** including structure / technology designs that enable low-cost modifications
- **Soft strategies:** such as information, capacity, institutional or policy, and also ecosystem-based adaptation like floodplain restoration (hard strategies include technology and structures)
- **Avoiding long-term commitment:** uncertainties increase further into the future so this gives flexibility to adapt to new circumstances while continuing to use land in the short term
- **Synergies:** that consider positive and negative externalities to other sectors and stakeholders

Maladaptive measures often prioritise short term gains over long term resilience. They are generally inflexible, costly to reverse and increase long-term vulnerability.

Table A3.1: Living with floods: adaptation measures

Prevention/mitigation

Measure	Benefits	Disadvantages/existing barriers	In a changing climate
Flood information and risk Assessment	Knowledge of risks is a prerequisite for risk avoidance, mitigation and preparation by local authorities, developers and individuals. Planning legislation and instruments can only be applied where flood information exists. Better mapping improves certainty for the insurance industry resulting in actuarially sound premium pricing. Accurate pricing signals level of risk. Large scale mapping can be cost effective (eg, QRA maps) and help form business cases for more detailed studies. Mapping a range of flood levels up to PMF improves versatility for both development planning and emergency management.	Detailed flood studies can be expensive. Different resolution of mapping can be used according to the needs of different communities. To assess risks, flood likelihood, behaviour and consequence need to be mapped and assessed. These are also important for planning emergency response. Due to cost, likelihood (areal extent) is sometimes the only factor mapped. Flood risk will change as the climate changes requiring iterative mapping. Catchment boundaries, appropriate for flood studies, do not coincide with local government boundaries. Local expertise can be lacking for both production and assessment of information. Flood risk changes in areas where development changes water flows. Many councils are reluctant to release flood information as it may impact property values. The National Flood Risk Information Program may improve availability.	Mapping that includes palaeological information (such as QRA maps) and PMF can help to compensate for Australia's short flood records (at most, 90 years) and enable planning for worst case scenarios. Production of flood information and risk assessment needs to include *future* climate scenarios, assets and settlement patterns. As climate change projections are revised, risk assessments also need to be updated. No-regrets, soft, low cost options for basic flood mapping.
New development restricted to areas of low flood risk	Reduces future exposure to high, long-term damage costs and social consequences.	Reduces risks for future development only. Identification of flood risk areas can be	Will help prevent increased damages from larger magnitude and more frequent flooding.

Measure	Benefits	Disadvantages/existing barriers	In a changing climate
	Reduces the need for emergency response capacity. Costs less than rectifying bad development decisions via relocation Costs less and is more effective than protecting badly sited development via structural measures (e.g. levees). Land unsuitable for development can be used for flood compatible purposes. USA examples of federal government instruments to encourage local application of development restrictions.	hampered by lack or inadequacy of local flood studies and mapping. The most common flood tool used to restrict development is the defined flood level, usually the 1:100 year flood. Work in the USA suggests this is not adequate, particularly for urban areas where consequences of flood and evacuation difficulties are greater. Potential hidden costs: 'down-zoning' can reduce property values and income from rates, raise insurance premiums, and expose local government to liability for compensation. Incentives and support are needed to balance this. Procedures to update planning schemes are complex and lengthy – up to 10 years. Needs reform to enable prompt revision. Legislation relating to indemnity has been amended in some states, but not in others for provision of flood information or zoning revision by councils.	Flooding will remain the most predictable hazard in terms of location. However, basing development restrictions on a 'static' 1:100 year flood line may result in people being located in areas of unacceptable flood risk if that flood line moves. Using a more conservative flood line (eg 1:500 year for urban areas), and considering MPF, SLR and palaeological information may compensate for lack of stationarity. Revised Australian rainfall and runoff tables are expected to address the incorporation of climate change scenarios. No regrets, flexible / reversible, low cost, soft, avoids long term commitment (of land use) Development of flood risk areas is very difficult to reverse and commits land use for hundreds of years.
Development planning legislation that consistently addresses flood risk	Consistent flood risk requirements in development codes and legislation will reduce ambiguity and exposure to risk. Risks will be reduced for vulnerable socio-economic groups.	Application of legislation requires flood information that can be lacking or inadequate. Consistent consideration of flood risk in legislation is currently compromised by non-	Will help prevent increased damages from larger magnitude and more frequent flooding. Those already most vulnerable are expected to be

Measure	Benefits	Disadvantages/existing barriers	In a changing climate
	Lower risk of pollutants in floodwaters. Greater likelihood that essential services and infrastructure will continue to function during floods. Victorian example where Catchment Management Authorities are designated referral agencies improves the consideration of flood in development planning.	compliance, satellite planning schemes, exemptions, omissions and non-mandatory provisions. Lack of legislation consistency and application often reflects policy conflict. Leadership is needed to resolve this. Flood risk consideration can conflict with: • short term development gains • affordable housing • cost of developing flood -free greenfields • increased rates income • reducing urban footprints • regional development objectives • priority projects • infrastructure needs A financial disconnect in that those gaining short term benefits do not pay the majority of damage costs.	disproportionally affected by climate change; providing higher risk 'affordable' housing now may be expensive in the long term. No regrets, flexible/reversible, low cost (in the long term), soft
Construction codes include flood resistant design and materials for buildings, essential services and infrastructure	Where selecting a site free of flood risk is not possible, construction standards increase ability to withstand floods, and to rapidly recover once flooding subsides. Reduces direct flood damage and indirect economic/social losses (eg, downtime, temporary accommodation, health). It is more cost effective to incorporate flood resilience into new development than to retrofit, particularly long term assets.	Raised floor levels can be an issue for the disabled and the elderly who have to negotiate steps. If building levels are higher than access routes, people may become trapped before realising they need to evacuate. If assessing the suitability of this measure, criteria need to address isolation risks, risk to life and risk of injury as well as asset lifecycles and the economic value of avoided damage. Not suitable for areas of more severe flood	Raised floor levels are only effective if the level is set sufficiently high and takes future risks into account. Using historical flood data or only raising to the 'new record' height may be insufficient. If changing flood patterns extend flood duration, isolation may be a growing issue. No regrets, low cost

Measure	Benefits	Disadvantages/existing barriers	In a changing climate
	Planning schemes can impose conditions on rebuilding (eg, Wagga Wagga). Some retrofit measures are low cost.	risk (eg high velocity or deep floodwaters). Some design elements (eg backflow prevention) may have ongoing maintenance costs. Increased upfront building costs compromise profit margins and affordable housing objectives, which are often prioritised over long term benefits.	
Voluntary relocation (including buy back schemes and land swaps)	Effectively removes people and assets from hazard areas and eliminates future damage. Most viable for repetitively flooded properties that are cheap to purchase. Billions of savings from avoided damages in some US examples. Overseas examples of minimising the cost (e.g. opportunistic pre-purchase of desirable property that can later be used for land swap (NL) Financing opportunities where synergies with other programs (eg, Lower Loddon buy back). Some costs can be recouped through resale of land (for specified use). 15% US disaster funding has to be used for mitigation, primarily relocation. Reduces future (federal) insurance liability. Vacated land can be put to other uses, including business, amenity, recreation, flood storage (see ecosystem approaches).	Up-front cost is the biggest barrier. Current NDR grants program inadequate to fund this systematically. Insurance payout alone is rarely sufficient to fund relocation, and land use will not change without government involvement. Unlike the USA, Australia does not provide national flood insurance so has less incentive to reduce private damages. Rarely used for entire towns due to expense. Community resistance is common. Land available for relocation is often undesirable or expensive. Needs measures to ensure vacated land is not later redeveloped. Eg, in the USA legislation and strong financial disincentives.	Climate change is expected to result in more frequent floods. As relocation becomes more viable with frequent flooding, this measure may increase in importance. Synergies High initial cost (long term savings) Not reversible
Ecosystem approaches	Mitigates floods for existing development.	Lack of public understanding about	Potential to address multiple

Measure	Benefits	Disadvantages/existing barriers	In a changing climate
(e.g. 'room for river' floodwater storage; levee setback; wetland restoration and connectivity; riparian vegetation; flood compatible farming systems, SuDS, mangroves)	Reduces flood depth, delays flood peaks and reduces velocity. Results in less erosion, less damage to buildings and infrastructure and greater warning time. Measures primarily need to be implemented in upper catchments (low value land). PES can diversify income for participating property owners. Low on-going administrative costs. Numerous co-benefits (eg, water quality, ecology, heritage, tourism, recreation, flood compatible business and farming, fisheries, groundwater replenishment). Compatible with integrated water management and win-win outcomes. Is highly effective for small-medium floods. For large floods needs to be used in conjunction with other measures. Commonly used as a measure to adapt to climate change flooding overseas. Australian examples from Leeton, Moreton Bay proposal, Victorian modelling in ENRC Inquiry.	hydrology leads to a common misperception that vegetation and meanders increase flood damage, leading to 'clear and straighten' activities. Ecosystem approaches need coordination across entire catchments but municipal boundaries do not coincide with catchment boundaries. Flood studies, land use, development and flood mitigation are planned and implemented locally. Catchment management is well developed in some states; other states have very poor provisions. Integrated water management can be complex to administer, requires expertise and capacity and is vulnerable to inflexible funding arrangements and siloed approaches. If land is transformed into public park, it needs ongoing public management. Unless ecological benefits are high, identifying a flood compatible private use may be cheaper.	climate change problems such as water scarcity (groundwater recharge), pressures on ecosystems and more frequent flooding. Flash flooding is expected to increase due to high intensity rainfall and sparsely-vegetated, drought-affected catchments. Ecosystem approaches slow floods, providing greater warning time. No regrets, flexible, soft, synergies Cost effectiveness depends on co-benefits, avoided damages, whether land needs to be purchased or use restricted, value of land, etc.
Enabling Betterment	Cost effective in the long term, particularly for areas likely to flood again and in the case of long term assets: reduces inspection, clean up, repair and replacement costs. Opportunistic adaptation, improving resilience at the point in time it costs the	Rebuilding to improved disaster resilient standards increases the cost of recovery. There is no guarantee another flood the same size will occur to justify increased standards. Damaged infrastructure needs immediate	Large magnitude floods are likely to occur more frequently with climate change. Recovery costs will also recur unless greater resilience can be built into assets. No regrets, lower long term cost (higher short term), some

Measure	Benefits	Disadvantages/existing barriers	In a changing climate
	least to do so. Some synergies possible, eg, bridge raising can have community benefits and improve flexibility of dam releases, reducing erosion (QLD Inquiry). COAG's NSDR supports betterment.	restoration. Lengthy cost benefit analysis and recovery grants approval processes for betterment are inconsistent with the need for immediate repair. Prior identification of infrastructure that might benefit from betterment could render it ineligible for betterment funding.	synergies.
Increased proportion of funds for disaster prevention / mitigation	The cost of mitigation is significantly less than the value of avoided damages. Some USA studies indicate very large cost savings. Overseas examples of funding arrangements, eg, USA legislation requires 15% federal disaster relief funding be spent on specified forms of mitigation (eg buy back, house raising). Potential synergies with social, environmental, economic goals. NL example of long term national adaptation strategy that coincides with broader national aspirations; win-win opportunities identified for communities.	Current federal spending on disaster prevention/mitigation is inadequate (~$30 million pa to be spent on resilience, divided by all states and natural disaster types and is not confined to prevention/mitigation). Disproportionate to generous disaster relief and recovery spending. Political barriers: the government that pays for mitigation may not be in power when benefits are realised; negative media coverage for insufficient relief and recovery effort encourages spending. Strong promotion to the public needed on benefits of prevention. Relevant for all Australians (eg, higher tax and insurance premiums, diversion of government spending from other priorities) Selection of mitigation measures needs to consider direct and indirect costs and benefits of measures and their alternatives.	Large magnitude floods are likely to occur more frequently with climate change, which will lead to ever increasing damage bills unless more is invested in prevention. No regrets, significant long term savings, soft, flexible. Potential for synergies, depending on prevention measures chosen and processes to identify win-win opportunities for communities.
Levees	Reduces frequency of small to medium flooding for existing development. While levees are high cost, local flood	High cost to build, repair and maintain levees. Consequences when levees fail are greater	Complex flood events can be exacerbated if key infrastructure is flooded, such as electricity sub-stations. Emergency response

Measure	Benefits	Disadvantages/existing barriers	In a changing climate
	damage is reduced. Best use is to protect compact high value assets (eg, existing urban and key infrastructure such as electrical and telecommunications facilities) in conjunction with contingency planning and development controls to prevent future need for levees.	than if they had not been there: • Dangerous high energy flooding when breach occurs. • Communities lack experience of smaller floods. • Perception that land behind levees is safe can a) encourage development, increasing potential damages; b) result in inappropriate building standards, c) inhibit contingency planning. Requires strong administration and on-going commitment: • assessment of off-site and cumulative impacts across catchments when planning; • design standards and approvals; • database of levee location, height, ownership, status; • identification of responsibilities; • maintenance scheduling; • access rights, inspection and audit; • contingency planning; • processes for approval/removal of temporary levees; • processes for removal of illegal levees; • strategies to minimise impacts of pseudo-levees • resolution of liability issues Negative externalities: transfers damage elsewhere; reduces flood storage area (increases flood depth, velocity and erosive power); damages natural assets, visual impacts. Levees not suitable to protect farmland due to low value of protected assets and high external costs.	largely depends on electricity, and the more complex the emergency, the more critical this will become. Levees can protect townships and rural residences against increasing frequency of flooding, though not necessarily increasing magnitude. Floods of increasing magnitude mean existing levees may no longer be adequate. Breaches and overtopping may become more common. High cost, not reversible, long term commitment, 'hard', negative externalities. Can be regarded as no regrets where used as a last resort for high value assets or key infrastructure.

Measure	Benefits	Disadvantages/existing barriers	In a changing climate
		Can impede natural drainage of floodwaters and so prolong floods. Flooding may also originate from sources the levee is not designed to prevent. Can interfere with flood intelligence (ability to predict flood behaviour)	
Sea walls, flood gates	Reduces frequency of flood damage and erosion for existing development. Particularly relevant for property subject to sea level rise and increased storm surge. Delays or prevents need to relocate. Mangroves could be considered as a low maintenance option to mitigate storm surge.	Similar cost and maintenance issues to levees. Can also have negative visual and ecological impacts. Contingency planning, retreat from high risk areas, development restrictions and conditions need to be rigorously applied to support structural measures or they could accentuate future risks.	Climate change is likely to increase the intensity (but not frequency) of cyclones in the north of Australia. Sea level rise and increased storm surge are expected to expose $226 billion of Australian coastal assets to flood damage and erosion. These measures reduce damage to existing assets and prolong their use. Avoids long term commitment (it can prolong settlement of increasingly risky areas; 'retreat' is not reversible)
Improved dam management	Processes for adjusting dam full supply levels could improve flood mitigation when major flooding is expected with a high degree of certainty. Assessments of dam capacity that incorporate climate change scenarios would help ensure infrastructure is able to manage increased inflows safely. Decision support systems, modelling and	Where dams are managed for the conflicting objectives of water supply, hydropower generation and flood mitigation, clear triggers, responsibilities and processes are needed to manage water levels. A dam can't be empty to catch flood peaks and full to deliver water or power at the same time. A high degree of confidence in long range seasonal forecasting is needed to justify	Flood events are expected to increase in frequency and severity. Dams will need to be able to safely withstand and manage increased inflows. Droughts are also expected to become increasingly severe, exacerbating the conflict between flood mitigation and water supply functions.

Measure	Benefits	Disadvantages/existing barriers	In a changing climate
	operation manuals can assist optimal timing of dam releases during and following floods to reduce damages. Communication protocols and better flood warning processes for those living directly below dams increases safety.	pre-release. Pre-release of water could compromise supply during drought if flooding doesn't eventuate. This could also have political fall-out. Needs careful risk assessment and community 'ownership' of processes. To optimise timing of releases during floods accurate data is needed above dams to predict inflows and models need to show high tides and peak river flows downstream. This information is sometimes lacking.	Hydrological studies underpinning dam management and safety assessment need to incorporate climate change scenarios. No regrets, soft, flexible
Additional flood mitigation dams	Reviews found dams mitigated peak flows during the 2010-11 floods regardless of whether they had a mitigation function.	Common perceptions that land below mitigation dams is flood proof encourages the development of that land and increases the consequences of large scale floods. (eg, DFLs can be adjusted to incorporate the assumed mitigation effect of dams, opening a wider area up for development) Elimination of small to moderate floods by capturing all floodwaters devastates natural systems. Land use systems that can accommodate smaller floods maintain the benefits of floods while minimising damages. The temptation to use empty storage for water supply during drought will be strong. Wivenhoe example reported in QLD Inquiry. Dam failure has high consequences for lives and property. Dams did not breach during 2010-11 events but the QLD Inquiry revealed safety issues.	Climate change will put natural systems under greater pressure. See also above, 'improved dam management' High cost, not flexible and rarely decommissioned, 'hard', negative externalities.

Planning/preparation

Measure	Benefits	Disadvantages/existing barriers	In a changing climate
Community Resilience: awareness of risks and remedies	Can lead to shared responsibility of risks and reduced vulnerability, eg, • purchase decisions • mitigation investment • planning and preparation • insurance cover • public support for adaptive flood measures • identification of opportunities	Unavailability or lack of property-scale flood risk information. Standards need to ensure quality information in understandable formats (see National Flood Risk Information Program) Shared responsibility is not automatic when risk information is provided. It is limited by economic and social capacity and cultural attitudes. Needs on-going commitment.	Individuals and communities will need to be more self-reliant: • Large scale complex disasters that overwhelm emergency services are more likely • Increasing numbers of costly disasters may reduce the availability of disaster relief and recovery funds No-regrets, low cost, soft
Community Resilience: planning and preparation	Helps populations in flood risk areas to be aware of risks, local disaster arrangements and steps needed for households to plan and prepare for emergencies. Planning can reduce damages and risks to life. Can tap into existing networks, eg, schools, community organisations, media. Existing programs, eg, FloodSafe, have been shown to improve preparedness. Relatively low cost.	Changing behaviour is more challenging and less effective than developing away from flood risk. The need for this measure signals past development failures. Ongoing commitment to community education is needed: • to ensure understanding of terminology, warnings, and consistent use of terms • to help people develop household emergency plans that ensure appropriate response. • to support business and public continuity planning Challenges to convince people to prepare for flood during prolonged drought.	If land subject to flooding expands due to climate change, the need for contingency measures will also expand. Resources are stretched in large scale floods. The more severe and widespread the event, the more people in flood prone areas will need to rely on their own resources to respond and recover, which requires preparation. Climate change is likely to increase the severity of drought, reducing awareness of the need to prepare for flood. No-regrets, low cost, soft

Measure	Benefits	Disadvantages/existing barriers	In a changing climate
Improved Emergency Management Planning	Appropriate facilities, personnel, expertise, equipment and processes are more likely to be available in emergencies if they are pre-planned.	Reviews found planning for floods was compromised by: • Lack or poor quality of flood plans • Planning that stops at administrative boundaries • Administrative boundaries do not overlap (eg of different response agencies) • Varying capacity and resources to produce quality plans • Poor oversight and approval processes for emergency plans • No legislative requirement for some levels of planning • Particular deficiencies were noted for evacuation and isolation planning, contingency planning, capacity and capability assessment, volunteer planning for clean-up.	Flood planning in some localities is not adequate to address complex emergencies. Emergency management planning needs to take into account possible changes to flood patterns as a result of climate change to ensure arrangements are sufficient to address risks. No-regrets, soft While relatively low cost, resources may be lacking.

Response

Measure	Benefits	Disadvantages/existing barriers	In a changing climate
Improved flood information and warning systems	Warnings provide time to move people and property to safer locations. This can potentially reduce flood damage by up to 80%. Improved alignment of areas of risk with coverage of warning systems. A key element of community resilience.	Most flood maps do not contain sufficient information to be useful for emergency response (eg, depth, velocity, range of likelihood scenarios, consequence). Type and distribution of gauges was insufficient in some areas. Councils incur ongoing maintenance obligations for data collection equipment which discourages uptake.	An increasingly fluctuating climate needs to be supported by accurate & timely data to support warning systems. Every review found that flooding in some areas was 'unprecedented'. With climate change, unprecedented flooding (location or severity) is increasingly likely. Better data

Measure	Benefits	Disadvantages/existing barriers	In a changing climate
		Funding of warning systems is piecemeal leading to gaps and inconsistent standards across catchments. Governance issues were identified (eg, need audit and oversight of warning systems; roles of BoM, state and local governments are unclear or inappropriate, leading to lack of accountability and poor service) 'Unprecedented' gauge readings can be disregarded as 'faulty', (eg, Helidon gauge upstream from Grantham). Verification mechanisms are need. There is a trade-off between warning timeliness and accuracy. Very vulnerable to electricity supply failure. Communications systems may not have sufficient capacity to deal with large scale emergencies, eg, websites and call centres. Flood warnings do not always elicit appropriate community action. Requires communication processes, content & terminology, pre-determined templates.	collection, coverage of warning systems and failsafe procedures for checking unusual readings would assist response where unexpected flooding occurs. More intense precipitation is likely to increase flash flooding, where there is a very small timeframe for collecting and processing data into flood intelligence and issuing warnings. No regrets. Management and behavioural aspects are 'soft'.
Robust emergency management framework	Clear roles, responsibilities, powers, procedures and accountabilities are more effectively able to manage emergencies. This becomes more critical the more complex the event (eg, where many different agencies are involved).	Needs to be supported by emergency policy, strategy, governance structure and legislation. Eg, Some legislation reflects out-of-date roles or does not provide required powers. Those assigned responsibilities do not always have adequate resources to carry them out.	Good management is especially important for large scale, complex flooding, which is likely to occur more often as a result of climate change. No regrets, flexible, soft.

Measure	Benefits	Disadvantages/existing barriers	In a changing climate
		Emergency procedures need to include scale-up mechanisms and triggers.	
All Agencies, All Hazards Approach, interoperability	Responders may lack sufficient resources in a large flood event to carry out designated functions: It is costly and impractical to maintain a large organisation of responders dedicated to flood when flood events might occur decades apart. Ability to pool the resources of different agencies in a large disaster improves response capacity. This approach reduces duplication and saves money (eg, separate facilities and technologies are not required for each agency) Incompatibility of systems and processes hampers communication and causes confusion in a high pressure situation.	Requires interoperability of communication systems, processes, regular joint agency training, IT systems and common information management portals between agencies (eg, so requests for assistance can be prioritised and matched with supply) There can be legislative barriers to using staff from other emergency agencies. There can also be liability or OH&S issues if untrained, unauthorised agencies assume control. 'All hazards' needs to be incorporated by agencies involved in risk assessment, emergency planning and development planning, equipment purchases. This approach has been an objective in Australian emergency management for over two decades but has yet to be achieved.	Complex emergencies, of larger magnitude, long duration, extensive areas affected, are likely to become more common with climate change. There are difficulties in supplying sufficient equipment and numbers of experienced, trained staff at all times if events are large or of long duration. The all agencies, all hazards approach improves capacity to respond to large, complex events. No regrets, flexible, soft Cost effective as use of resources is maximised
Evacuation and Isolation	Minimises injury and loss of life.	Evacuation and isolation planning and procedures are often inadequate or lacking. Planning is needed for evacuation trigger points, routes, facilities and support. Specific issues raised by reviews include: • facilities need to suit the hazard(s) faced (eg, not floodable; cyclone proof) and scale of event • arrangements needed for informal evacuation centres, especially for isolated communities	Greater numbers of people may be displaced or isolated for longer periods of time if flooding increases in severity, extent or duration. Sea level rise will increase storm surge and good evacuation planning will be critical to the safety of some coastal communities.

Measure	Benefits	Disadvantages/existing barriers	In a changing climate
		• facilities need to be suited to function (eg using evacuation facility criteria) • need to incorporate NGO groups in planning, communication and timing of evacuations • identification of vulnerable groups needing evacuation assistance • need to plan processing of evacuees and support services	No regrets, flexible, soft
Protection of essential services	Essential during emergency response for providing timely warnings and updates, provision of data for responders, communication and coordinating response.	Appropriate siting and design are the most effective ways of ensuring continued operation during floods. Essential services cannot always be sited out of harm's way (eg, legal obligation to provide services to development regardless of where it is sited) Appropriate risk mitigation strategies are sometimes lacking. Risk assessment and business continuity planning are needed for all essential services, including community services. Protective measures need to be planned in advance, offsite impacts assessed and incorporated into broader community emergency management plans.	There is likely to be an increase in the number of large, complex flood events involving multiple agencies. The more complex the emergency, the more critical essential services are to manage it. No regrets. While physical protection is 'hard', it may be temporary and reversible (eg, sandbags). Improved planning and management are 'soft'. Long term avoided costs (to both companies and society) but higher upfront construction / replacement costs
Improving the arrangements for response volunteers	Increases the number of people available to help in emergencies at minimal on-going cost.	If using volunteers, aspects such as liability, training, coordination and supervision need to be addressed. Legislative support may	The number of personnel required during a complex emergency is enormous and

Measure	Benefits	Disadvantages/existing barriers	In a changing climate
		be needed (eg, in VIC there are legislative barriers for SES volunteers to exercise control functions) Volunteers in some areas are under resourced (eg, some QLD SES units fund raise 40% of their operating budgets). Incorporation of volunteers into response and recovery requires good planning and flexible staffing arrangements. There are limits to volunteer capacity to engage (eg, competing demands on time for acquiring competencies) Response agencies compete for the same volunteer pool (eg, SES and Fire brigades).	outside routine operational capacity. Resources will be stretched, especially if severe events become more frequent. No regrets, low cost, flexible, soft

Recovery

Measure	Benefits	Disadvantages/existing barriers	In a changing climate
Insurance for flood	Primary means for businesses and individuals to finance recovery. Reduces the need for disaster relief. Premium pricing can raise awareness about level of risk. This can encourage people to consider mitigation, especially if pricing offers incentives to do so. Those incurring the risk pay the costs associated with it instead of relying on others to do so.	Insurance creates a potential moral hazard by insulating people from the financial consequences of settling in risky areas. In areas of high risk, insurance may be unavailable or unaffordable, compromising ability to recover. Many of those who live in flood prone areas (eg semi-industrial or rural) are poor and unable to afford high insurance premiums. Living elsewhere may not be a choice. They also have fewer savings to recover. Such people are highly vulnerable to climate change.	An IPCC paper suggests a doubling of CO2 will increase flood damages between four and ten-fold in three Australian drainage basins (Bates et al, 2008). If severe disasters occur more regularly, or in areas not built to resist flood, insurers can expect ever increasing damage costs. The more widespread and severe the event, the less capacity the insurance industry has to rapidly assess

Measure	Benefits	Disadvantages/existing barriers	In a changing climate
	The USA national flood insurance program has introduced many elements to improve future flood resilience. Eg, supplementary insurance to enable rebuilding to a better standard. Rapid recovery is the most successful. Area hydrology reports rather than site specific reports were found effective to speed up the assessment process (where cause of flooding needs to be established).	Cultural and social influences may prevent uptake eg, gambling on the (un)likelihood of a flood; perception of government responsibility for disasters. Uncertainty and the need to be competitive prevent climate change from being factored into risks and pricing: risks may be underestimated. Insurance pay outs are only sufficient to repair damage, not rebuilding to improved standard or relocation. Where insurers offer incentives to mitigate, they need to be careful to promote adaptive solutions and alternatives.	damage, which can delay clean up and recovery. Climate change risks are more likely to be factored into pricing if they are included in local flood studies. Those already vulnerable will be impacted most heavily as they have limited capacity to recover. This challenges the wisdom of affordable housing policies that don't consider flood risk, long term losses and psychological impacts. No regrets, flexible, soft
Processes to ensure rapid and enduring recovery	Rapid clean up reduces indirect costs (eg, downtime for business, spoilage, costs of temporary accommodation, stress) Volunteers greatly improve capacity to recover following a large disaster. Upfront funding for local governments of 50% of expected disaster costs via trust fund was successful in helping speedy recovery.	Processes to identify people needing assistance can be inefficient, (eg, misperceptions about privacy laws resulting in the provision of the same information to multiple agencies; lack of clarity about agency roles leading to duplication and omissions). Needs good planning, systems, use of protocols. In large disasters insufficient capacity prevents rapid assessment and repairs. Speed and effectiveness of recovery programs and deployment of Community Development Officers vary from state to state and between disasters. These are needed as early as possible. Recovery grant and reimbursement claim processes are complex and inclusions sometimes unclear or misunderstood. Currently grants schemes do not increase the	The greater the flood event the more people there will be requiring assistance and infrastructure requiring repair. Duplication and bad planning can waste limited capacity. No regrets, flexible, low cost, soft

Measure	Benefits	Disadvantages/existing barriers	In a changing climate
		disaster resilience of rebuilds and generous provisions have the potential to act as a disincentive to responsible land planning (see prevention section). Grants to individuals are badly targeted and too small to help those worst affected. Hasty recovery can ensure continued exposure to risks and lack of planning controls facilitates this in some areas, eg, the Brisbane Review noted rebuilds or repairs do not have to comply with improved standards and are not subject to approval. Use of volunteers in initial clean up (eg ~50,000 in Brisbane) needs good planning and liability issues need to be resolved. Where coordination is bad, volunteers can be a hindrance.	

Source: Hallegatte (2009).

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